Local Sustainability 1

Konrad Otto-Zimmermann
Editor

Resilient Cities

Cities and Adaptation to Climate Change
Proceedings of the Global Forum 2010

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Local Governments for Sustainability

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Foreword

Preparing for the impacts of climate change on the world's cities is a major challenge of the twenty-first century. No-one today can really foresee the predicament in which a town or city will find itself 10, 20 or 30 years down the road. We must bear in mind that the greatest impacts of disasters resulting from climate change begin and end in cities.

Prevention can be greatly enhanced through better and smarter land-use planning and building codes so that cities keep their ecological footprint to the minimum, and ensure their residents, especially the poorest, are protected as best as possible against disaster.

By far the most vulnerable to natural disasters, the urban poor often have no choice but to live in sub-standard housing in places often prone to floods or landslides – places which lack even the most basic human services and where no-one else wants to live. When disaster strikes they have few or no private assets or social safety nets to fall back upon.

Unless the world takes decisive action, this problem may well worsen in coming decades ahead. Science tells us that already rising sea levels, cyclones, heat waves and droughts, changing rain patterns and other impacts of climate disruption are becoming increasingly manifest.

Furthermore in coming years, vulnerability increasingly will become urbanized given that already more than half of the world's people now live in cities, and that projections show that by 2050 this figure will rise to 70%.

Similarly the number of slum dwellers is also set to rise. Make no mistake, it will be those living in absolute poverty, especially in the developing countries, who will suffer most in any climate crisis.

It is heartening that local leaders are beginning to find solutions to these problems. Cities are assessing which communities, places and sectors are most vulnerable. They are investing in climate proofing their infrastructure networks.

They are integrating adaptation action in urban planning initiatives and municipal finance scenarios. Additionally, the international community is slowly waking up to the need and obligation for cities to become more resilient to the impacts that we expect from a changing climate.

We thus salute the Resilient Cities Congress and commend ICLEI for taking the lead in forging the partnership of organizations supporting the Congress.

As a former mayor I know that local officials and leaders often learn best from one another, and this Congress offers a golden opportunity. At the same time, the Congress is also an opportunity for all who deal with the very important urban dimension of climate change to interact with one another.

And finally the Congress offers city officials and their organizations an ideal opportunity to forge a common position from which to lobby national governments and the international community for a fair share of the adaptation resources pledged – resources cities so desperately need to become more resilient.

UN-HABITAT is honoured to serve on the Program Committee of the Resilient Cities Congress, and I am pleased to serve as a Patron of the Congress. The present proceedings document from the inaugural Congress of 2010 offers a wealth of insights into how to make cities more resilient.

At the same time I wish the distinguished delegates in the Resilient Cities Congresses every success with their deliberations now and in the future.

Dr. Joan Clos
Under-Secretary General United Nations
Executive Director UN-HABITAT

Authors

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Acknowledgements

The first annual global forum on cities and adaptation to climate change, Resilient Cities 2010, took place from 28 May to 30 May 2010 in Bonn, Germany back to back with the United Nations Climate Talks. Hosted by ICLEI – Local Governments for Sustainability, the World Mayors Council on Climate Change and the City of Bonn, the congress was a unique starting point in addressing the crucial topic of adaptation in urban contexts.

With over 500 participants from 53 countries worldwide, this event far surpassed our expectations, generating significant interest and demonstrating the need for such a global platform.

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All of us look forward to continuing the exchange and dialogue at Resilient Cities 2011.

Konrad Otto-Zimmermann
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Part I
Introduction

Chapter 1
Building the Global Adaptation Community

Konrad Otto-Zimmermann*

An overwhelming body of evidence suggests that the Earth will likely experience a doubling of pre-industrial levels of greenhouse gases within the next 20–50 years, causing a rise in global mean temperatures. While estimates of the impacts of this temperature increase range from moderate to catastrophic, even conservative scenarios of global warming could have severe impacts on natural and human systems. The Inter-governmental Panel on Climate Change indicates that lower temperature increases could result in greater vulnerabilities regarding food supply, infrastructure, health, water resources, and coastal systems, while intermediate estimates point to significant losses in biodiversity, decreasing global agricultural productivity and glacial melt.

Nearly two decades ago, in Rio de Janeiro in 1992, the international community reached a global consensus on the reality of global warming, the necessity to reduce the greenhouse gas emissions, and the need to prepare for the impacts of climate change. Heads of Governments and States adopted the United Nations Framework Convention on Climate Change. This development in international policy was accompanied by parallel commitments and actions at the local level, with a number of networks, platforms and associations emerging in response to the climate challenge. The first Municipal Leaders Summit on Climate Change, convened by ICLEI at the United Nations Headquarters in New York in January 1993, saw the launch of the first and largest network of local governments concerned with climate change – the Cities for Climate Protection Campaign. The Campaign and its spin-off programs continue to play an instrumental role in assisting municipal councils to establish targets, time lines and strategies for implementation.

The Local Government Climate Roadmap, paralleling the Roadmap agreed by the 2007 UN Climate Change Conference (COP13) in Bali, Indonesia, was developed by

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local government networks advocating for the greater role of cities in climate protection in a strong and comprehensive post-2012 climate agreement. The Roadmap has become an important tool in rallying local governments in the fight against climate change and involves the cooperation of a number of local government organizations including ICLEI, United Cities and Local Governments (UCLG), Metropolis, the C40 Climate Leadership Group and the World Mayors Council on Climate Change. These organizations continue to illustrate how municipalities and associations, through sustained cooperation and advocacy efforts, have actively responded to the climate question and have transformed global agreements into local action.

While a crucial response, the early policy and campaign achievements focused almost exclusively on mitigation: creating emissions inventories, defining targets, establishing local climate action plans, implementing these and quantifying results. As the inevitability of climate change becomes more apparent, an understanding has grown that we do not only need to address the causes, but also the impacts of climate change Even as we pursue action to prevent further rising of global temperatures, there will be severe consequences of our patterns of production and consumption.

1.1 Cities Will Feel the Brunt Force of Climate Change

There is a growing recognition that urban areas will be profoundly affected by climate change. Whether in coastal areas, inland, or in high-altitude locations, cities concentrate economic activity, population, and critical infrastructures. Therefore, they also concentrate risks associated with climate change.

Cities are vulnerable to changes in temperature due to the high concentration of population, infrastructure, goods and commodities. Locations in high risk areas, such as low-lying coastal zones, floodplains and hillside slopes further aggravate urban vulnerabilities. The impacts of climate change are felt even harsher in cities of low and middle-income nations, where uncontrolled growth in high-risk areas is the norm and municipal agencies often lack the capacity, and in some cases the will, to cope with vulnerable areas and populations. At the same time, highly developed and industrialized urban areas are relying on structures and systems that are incapable of coping with climate change risks such as natural disasters. It is becoming clear, that climate change will profoundly affect cities regardless of their wealth or geographical location.

As urban areas today accommodate half of the global population, and will host two thirds of all humans by 2050, there is the need to focus on the adaptation of cities and urban communities to climate change.

Investments made in the coming decades will be of utmost importance not only with regard to mitigating further climate damage, but also in terms of how well they equip cities to respond to impacts within predicted climate scenarios. This notion of investment goes beyond the implementation of technical solutions sheltering cities from predicted climate impacts; it needs to include advances in human and social capital, institutional capacity, and inter-city and regional cooperation.

Local governments are the units best placed to implement informed decisions in areas such as land-use planning, building standards, freshwater supply, wastewater and waste management, transportation etc.

1.2 Emergence of an 'Adaptation Scene'

ICLEI has observed these developments for the last 20 years. In response to a surge of interest and resources, many sectors have begun positioning themselves around the theme of adaptation to climate change. Universities and think-tanks are embarking upon new streams of research, UN agencies are actively seeking their role in the field in a variety of ways, consultancies and other companies sense new business opportunities, along with other groups and actors increasingly engaging with this theme. Local governments are becoming aware of the need to pursue more strategic and long-term planning decisions in response to climate impacts. And while this broad movement towards adaptation, what one may call 'adaptation scene', is a step in the right direction, now is the time to ensure that adaptation is understood and implemented at the local level in a wise and informed way.

Climate change science and policy have coined two key terms, 'mitigation' and 'adaptation', and consequently, the expert world has begun to divide policies, actions and finance mechanism into mitigation and adaptation.

With the increased recognition of the need for climate change *adaptation* besides *mitigation*, the greenhouse gas reduction community has made noticeable moves to cover adaptation as an adjacent field for their business. This has led to an industry with strengths in emissions monitoring and reductions, energy technologies, etc. to move into a field where professional expertise in long-term urban planning, infrastructure planning and finance etc. is required. The question that stood in the room was whether a professional gathering better suited to the long-term strategic needs of cities preparing for the future was called for.

1.3 A Global Forum on Urban Resilience

ICLEI felt it was time to gather representatives of the adaptation scene in order to take stock of the players, actions and challenges in this field, to share views on the adaptation challenges ahead, and to assess whether the necessary actions are being taken.

Informed decisions require inspired local leadership, effective governance arrangements, and supportive financial architecture. An assessment of current gaps between knowledge and capacity, between need and action was needed.

There was a further interest in connecting the leaders in urban adaptation and accelerating the transfer of knowledge and experiences between the various actors.

As an organization that works to strengthen local government capacity and collaboration, it was of great importance to ICLEI to explore whether adaptation is being appropriately positioned within the remit of local governments and their municipal administrations, and whether local authorities are paying adequate attention to issues such as the allocation of staff resources or to the nature of investments in goods and services. ICLEI also identified the need to create a shortcut between the needs of cities and the responses in preparation by international agencies, donors and finance institutions. A global forum seemed the best way to facilitate this shortcut and to speed up cities' adaptation to climate change and urban resilience-building.

With these goals in mind, ICLEI initiated a global forum designed as a series of annual world congresses and convened Resilient Cities 2010, the 1st world congress on cities and adaptation to climate change. Given the magnitude and complexity of the adaptation issue, the congress series has been designed to ensure a sustained commitment to the theme of urban adaptation to climate change.

The overwhelming response to the Resilient Cities call for contributions illustrated the need for such a forum. Over 200 papers and 25 panel proposals came from practitioners, academics and local governments across the world, and the congress was supported by the largest partnership of global institutions on adaptation to date, with nearly all relevant international organizations – from UN bodies and development banks to professional networks.

The final program consisted of four plenaries and 150 presentations arranged within 48 thematic sessions surrounding topics such as multi-level governance, vulnerability and risk assessment, inclusive adaptation planning, tools and implementation and regional cooperation. Presentations and discussions emphasized the significance of early and sustained collaboration across sectors, additional training needs and the critical role that strong political leadership plays in driving adaptation policies and programs.

The Mayors Adaptation Forum, jointly convened by the World Mayors Council on Climate Change and the United Nations International Strategy for Disaster Reduction (UNISDR), saw Mayors discuss the integration of adaptation science and policy-making. The Forum launched UNISDR's "Making Cities Resilient" campaign, aiming to commit city leaders to a checklist of essential actions. The Bonn Declaration, a key outcome of the Forum, was pressing for enhanced recognition and involvement of local governments within global climate governance and seeking to facilitate direct access of cities to global climate funds ahead of the UN climate talks in Bonn and Cancun in 2010.

The first Resilient Cities congress surpassed expectations. A truly global forum, the congress was a solid starting point in helping urban stakeholders identify and respond to key issues affecting their capacities and helped generate some consensus on principles of adaptation practice. These included the need to join 'top-down' and 'bottom up' approaches, to facilitate community involvement in early stages of planning processes rather than later stages of implementation, and to embed resiliency goals in communities rather than isolate them in city departments alone. Local practitioners stressed the importance of securing a common language tools and approaches both within cities and across regions. Above all, it was stressed that adaptation should not compete with existing priorities within cities, but be integrated into existing policies for different sectors.

The congress also established key themes and deficits that require renewed attention, such as the nature of adaptation project formulation and funding mechanisms, the potential for collaboration between cities and the private sector and the intersection between adaptation and development assistance. These areas will help form the focus of Resilient Cities 2011.

1.4 This Publication

This publication brings together the key contributions emerging from the first global adaptation forum, Resilient Cities 2010. Submissions highlight the current themes and approaches being explored by leaders emerging from the field of adaptation – academics, municipal experts and private sector practitioners.

The contributions address adaptation from a number of angles. From descriptions of pending impacts and vulnerabilities and discussions of the conceptual frameworks underpinning adaptation to analysis of local adaptation plans, projects, and partnerships, these papers illustrate the diversity of issues contained within this theme. Together, they paint a broader picture of existing concerns as well as the multitude of solutions being employed around the globe. They draw attention to the significance of development choices and to the crucial role that basic services, such as adequate drainage, sanitation, and land-use planning can play in making cities resilient.

It is hoped that this volume will inform and inspire future dialogue toward building resilient cities.

Impacts of Climate Change on Cities

The following table shows existing and projected impacts of climate change on crucial social systems and urban sectors within cities.

	Temperature change; heat and/or cold waves	Drought	Extreme precipitation patterns and flooding	Storm surge	Sea-level rise/ coastal erosion	Other impacts common to each vertical category
Economic activity	• Shifting energy demands, requirements and costs • Shifts in tourism and recreation	• Disrupted power generation • Water shortages for industry	• Destruction of commercial, governmental and private property • Damage to local infrastructure • Revenue loss from disrupted travel and business opportunities/activity • Threats to essential services, energy and telecoms, etc.	• Economic losses from damage to infrastructure • Tourism • Evacuation costs	• Reduced waterfront property values • Catastrophic loss of coastal assets	• Impacts on productive sectors; e.g., agriculture and fisheries • Loss of livelihood • Pressure on insurance systems
Urban infrastructure and built environment	• Pavement and track damage from extreme heat • Intensified urban heat island effect	• Difficulties for inland waterway transportation systems • Ground water subsidence	• Overwhelmed wastewater treatment facilities and urban drainage systems • Disruption of transportation system: temporary and permanent flooding of airports, roads, rail lines and tunnels • Waterlogging	• Damage to ports, marine infrastructure, settlements, roads, bridges, pavement, electricity, etc.	• Losses to coastal infrastructure • Water infrastructure jeopardized	• Burden to protect, repair and maintain infrastructure • Loss of aesthetic appeal to physical environment • Threat to housing, particularly low income/informal settlements, urban poor

Human health and safety	• Air quality: respiratory illnesses, skin complaints • Thermal comfort • Health risk for heat-sensitive populations (i.e., young and elderly) from heat stroke and dehydration • Increased risk of water contamination	• Malnutrition and dehydration • Reduced water availability for sanitation and drinking	• Spread of water borne and airborne (vector) diseases; e.g., malaria, dengue • Drowning deaths	• Flood, debris and wind casualties	• Saline intrusion: effects on drinking water, resultant dental disease	• Resource conflicts • Happiness/well-being
Vulnerable communities/ urban poor	• Heat fatalities due to poor air circulation in congested slums and lack of access to air conditioning	• Vulnerability of slums/informal settlements where water is scarce • Large rural migration into cities	• Urban poor are forced to settle in hazardous flood plains	• Displacement of vulnerable communities • Forced migration/ relocation	• Displacement of low lying coastal communities, river • Communities and other vulnerable areas	• Loss of livelihood in many sectors • Pressure on women, elderly and the very young
Agriculture and ecosystem services	• Thawing of permafrost • Loss of melt water • Threat of more severe wildfire incidents	• Urban forestry (e.g., provision of shade) and crop loss • Threat of more severe wildfire incidents	• Habitat loss • Soil erosion • Water logging • Mudslides	• Destruction of fisheries and other coastal and inland systems (e.g., coastal dunes)	• Saline intrusion: effects on irrigation water	• Land use change, changed cropping practices • Food security • Relocation of jobs dependent on well-functioning ecosystems • Loss of urban biodiversity, threats to coastal vegetation, especially mangroves

Sources: ICLEI – Local Governments for Sustainability (2010) Climate Impacts by Region, ADAPT program, ICLEI USA: http://www.icleiusa.org/programs/climate/Climate_Adaptation/climate-impacts-by-region

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Part II
Describing Impacts at the Local Level

Chapter 2
Introduction: Describing Impacts at the Local Level

Lucinda Fairhurst

Climate change is expected to have severe physical, social, environmental and economic impacts on both developed and developing cities across the globe. Current global climate projections indicate that changes are likely to result in increased temperatures, sea level rise (temporary and permanent inundation), changes in rainfall and precipitation patterns (flooding and drought), changes in wind speed, and changes in the severity and frequency of extreme events. The risks and impacts associated with these climatic changes pose a serious threat to the reputations of cities as service providers and their ability to meet their own targets for growth and development.

These impacts may not always occur as a direct result of climate change, but can often emerge from a complex chain of events. Many governments and communities have strategies in place to deal with routine climate variability, however, in light of projected climate change, cities cannot simply rely on the assumption that conditions will continue as they have for the last 50–100 years. For developing and developed cities worldwide, increasing climate variability will raise new challenges that will require sound management in order to ensure resilience and enable economic growth into the future.

Many cities are set for rapid urban expansion from rural-urban in-migration. Presently, many of these cities, particularly those in the developing world, suffer from insufficient and unsustainable growth. Populations from rural hinterlands settling in and around cities in pursuit of better livelihoods need access to basic services such as housing, clean water and sanitation, transport, education, and health services. How cities manage both short- and long-term impacts of climate change will have consequences for communities working and living in these urban centres, most notably for the rapidly expanding poor communities that are often located at urban edges with little access to infrastructure and other services. Integrating climate change adaptation considerations into development planning, then, is considered critical in meeting this challenge. Mainstreaming climate change by integrating

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the risks and opportunities it poses can also help enhance the adaptive capacity and resilience of cities and the communities that fall within their jurisdiction presently and in the future.

Globally, there is limited information available at the city level about sustainable, effective and efficient development alternatives for cities. This deficit increases the reliance of cities on carbon fuels and their vulnerability to the immediate and long-term impacts of climate change. Empowering cities to accommodate these changes requires an awareness of the risks associated with projected climate change and an understanding of the relative significance of these risks and impacts.

Within this context, the following chapters focus on the identification and understanding of the most immediate and compounding impacts of climate change in cities in Africa, Asia and Europe in an effort to identify what adaptation measures should be adopted to assist the most vulnerable sectors and communities within these urban centres. Detailed descriptions of the methods used to arrive at these findings are also offered.

Climate change is shown to have significant impacts on the development and economic base of local regions by reducing their ability to grow and thus maintain carrying capacity. Cities may also face a reduction in their ability to generate and/or raise income. This is likely to be accompanied by an increase in demand for service provision; e.g., measures to combat rising temperatures and flooding (in the case of local governments) or addressing the increased vulnerability of women to drought (at a community level).

In the following chapters, the links between climate driven phenomena and their current and future impacts within cities are offered through a variety of interdisciplinary approaches, often drawing from social research and data gathered from respondents. Several chapters also demonstrate the importance of establishing and maintaining cross-sectoral, multi-dimensional relationships for sharing knowledge and experiences relating to extreme climate events. We hope that readers find these writings informative in the range of innovative methodologies and measures that they present. Building knowledge in this direction, both qualitatively and quantitatively, is an important step for enabling cities to respond to climate change, and forms the ongoing challenge of research into resilient cities.

Chapter 3
Understanding Potential Climate Change Impacts and Adaptation Options in Indian Megacities

Diana Reckien, Martin Wildenberg, and Kaushik Deb

Abstract This study examines the impacts of strong rain events on local stakeholders in New Delhi, India, with the aim of developing effective adaptation and impact abatement options. Impacts are presented for various social groups – i.e., street food vendors and service providers, students, planners, other professionals and researchers – and analysed with respect to transportation, energy, water, health, food security and other issue areas. Under progressive climate change, strong rain events are projected to increase. Without adaptation, then, impacts will also increase. We use a fuzzy cognitive mapping approach and let stakeholders draw cause-effect networks. By 'cutting' certain cause-effect relations, its after-effects can be reduced and any such measure can be regarded as an adaptation option. Analysis reveals that local service providers and street food vendors are substantially worried about the economic losses connected with strong rain events, while other social groups care more about traffic jams and impacts on health. Scenario runs have shown that a climate change adaptation strategy that involves a reduction of local flooding would substantially reduce a multitude of impacts for all.

Keywords Climate change adaptation • Climate change impacts • Fuzzy cognitive mapping (FCM) • India • New Delhi • Socio-economic groups

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3.1 Introduction

The Intergovernmental Panel on Climate Change (IPCC) has identified ‘the interactions between climate change and urbanisation’ as a key vulnerability of settlements and society, ‘most notably in developing countries, where urbanisation is often focused in vulnerable areas, especially when mega-cities and rapidly growing mid-sized cities approach possible thresholds of sustainability’ (Parry et al. 2007: 374). The assumed high degree of vulnerability is related to (a) the overall fragility and sensitivity of urban ecosystems arising from resource overexploitation, (b) the expected increasing magnitude and frequency of climatic events, and (c) a particularly low adaptive capacity rooted in issues connected to the development context. The central aim of this analysis is to investigate effective adaptation options to reduce urban vulnerabilities for different social groups apart from traditional thinking and western-centred growth patterns.

The presented ongoing case study is motivated by worrisome climate change projections that for an intermediate global emission scenario (A1B) show an increase in annual mean temperature of about 4°C, a significant increase in the frequency of heat waves, and a significant increase in average rainfall intensity. However, despite the obvious and devastating impacts of recurring extreme events in many parts of India, the perceived extent of the impacts may vary between people, for instance, between directly affected persons and scientific experts. In addition, there may be differences in perceptions due to a variation in socio-economic and cultural backgrounds of different stakeholder groups in affected regions, such as local service providers (LSPs) that work under the open sky on the street and planning experts who do not.

To ensure that the analyzed impacts accurately reflect local understanding and affectedness, we conducted interviews with local stakeholders in the capital city of India, New Delhi. One of its largest urban residential agglomerations, Vasant Kunj, in the south of the city is the spatial focus of investigation. Vasant Kunj is mainly a residential area for the well-situated middle class. There is also an institutional area demarcated within Vasant Kunj that houses universities, think tanks and other organizations. We employ the interview method of fuzzy cognitive mapping (FCM) (Özesmi and Özesmi 2004), which discloses individual knowledge and perception by letting local people draw impact networks. An extensive investigation with ‘on-street and small shop service providers’, planners, other professionals, researchers, and students yielded 67 interviews in total. We discuss one particular weather event that will potentially alter in number and intensity under progressive climate change, namely, strong rain events. We present the outcome of the statistical analysis, compare the different stakeholder groups and two potentially suitable adaptation scenarios.

3.2 Methodology

Climate or weather impact networks describe the cause-effect relations between weather events and particular aspects of society; e.g., transport, food security and health (Reckien et al. 2009). They represent one form of the system’s comprehension by stakeholders and community members, serve as a visualization of the system's functionality, and demonstrate the methodological approach used to assess different adaptation measures. 'Cutting' certain cause-effect relations represents a potential adaptation option that enables calculation of the consequences for other factors in the map, assessing the effect range and effectiveness of adaptation options, and discussing the costs as well as the (political, cultural, etc.) suitability of certain adaptations.

The FCM approach leads to fuzzy cognitive maps (FCMs), which are graphical representations of causal relations in a given system in the form of a directed network, as perceived by stakeholders. FCMs indicate the importance of causal functions between factors of the system by using quantitative numbers, which are also given by the interviewee (Kosko 1986; Özesmi and Özesmi 2004). The variables can be physical, measurable entities as well as qualitative, aggregate or abstract ideas, such as ethical, political or aesthetic issues. Detailed descriptions of the approach and its application can be found in Özesmi and Özesmi (2004), Isak et al. (2009) and Wildenberg et al. (2010).

Cognitive maps and FCMs are particularly valuable in situations where detailed scientific data are lacking but local stakeholder knowledge of people is available, and for complex problems, when many parties are involved and no straight-forward solution is deducible (Özesmi and Özesmi 2004). FCMs have a long history in social-ecological research and the management of complex environmental management problems. Knowing how a person perceives and understands his or her environment can substantially help in managing a system. In our application, this refers to the following assumptions: (1) significant impacts are remembered and only those that are remembered are significant; (2) significant and negative impacts need close attention in order to better adapt the system and ameliorate the situation for the stakeholder groups; and (3) an active intervention in the system (e.g., adaptation to climate impacts by the stakeholders) is in fact only possible for those cause-effect relations that are perceived and understood. The latter is independent of whether the relation is 'true' or not. We hypothesize that it is important to understand the perception of climate and weather impacts because people cannot adapt or will not intervene in a detrimental cause-effect relation if they do not first 'see' the relation.

Different stakeholder groups were approached and asked to reflect on the following question: 'What happens in Delhi during strong rain events and how does that affect you?' Interviewees had first to note down what comes to their mind in a brainstorming mode. They were then asked to use the same variables and, if possible, relate them to each other. In a third step they had to indicate the direction of influence (positive or negative) and to assign weights to each of the arrows/causal functions. We additionally collected profession, age, sex, and time lived in Delhi as socio-economic indicators.

The cognitive maps (both single and aggregated ones) are analysed according to network analysis statistics. An aggregated map (and matrix) combines the views of all people interviewed in one stakeholder group for which equal concepts from different stakeholders were summarized in one factor and the averages weighted. The resulting maps are called 'cognitive interpretation diagrams' (CIDs) (Özesmi and

Özesmi 2004: 53). CIDs can be visually compared by clustering impacts according to issue areas, such as transport, health, food security, water issues, personal way of living, etc., and across stakeholder groups.

The outcome of different management scenarios of the FCMs are also computed and account for different adaptation options. We will compare two adaptation scenarios by 'cutting' different cause-effect relations and looking at the influence on other variables in the networks. We use the statistical software FCMappers developed by Michael Bachhofer and Martin Wildenberg to calculate network statistics and adaptation scenarios. The software is freely available at www.FCMappers.net.

3.3 Results

3.3.1 Climate Change Impact Networks from Primary Sources: Fuzzy Cognitive Maps

In total, 67 valid FCMs were analysed. Table 3.1 gives an overview of the distribution across stakeholder groups.

3.3.2 Individual Maps: Statistical Analysis

The network statistics for single maps, averaged over all maps in a stakeholder group are shown in Table 3.2.

The maps of professionals have the highest number of factors per map, followed by students, planners, researchers and local service providers. Professionals therefore see many different impacts, or name certain issues in great detail. However, it is also the professionals who had the highest difference in the number of mentioned factors across single maps indicating its diversity. Local service providers drew the smallest maps with the lowest number of factors on average. One map consisted of only two nodes and one arrow. Local service providers name fewer impacts, and name the issues in a more aggregated way. They are a relatively homogenous group,

Table 3.1 Overview of interviews conducted on rain events per stakeholder group

Stakeholder group	Number of valid maps
Planners	7
Local service providers	26
Professionals	13
Researchers	7
Students	14
Total	67

Table 3.2 Network statistics for single maps, averaged and clustered in stakeholder groups

New Delhi – Strong Rain	Planners	Local service providers	Professionals	Researchers	Students
Size of maps					
Average (factors/map)	10.29	7.92	13.69	9.22	11.07
MIN number of factors	7	2	5	7	6
MAX number of factors	14	15	27	14	22
DIFF (MAX, MIN)	7	13	22	7	16
Density of maps					
Average [(connections/factors) per map]	1.07	1.19	1.13	1.09	1.18
Average density [C/N(N – 1)]	0.12	0.22	0.12	0.14	0.13
Complexity – influence diversity					
Average [(receivers/factors) per map]	0.35	0.42	0.43	0.35	0.41
Average [(emitters/factors) per map]	0.09	0.20	0.12	0.17	0.12
Average (receiver/emitter)	4	2.65	4.83	2.29	4.42

when judged from the indicator 'size of maps'. Researchers are most homogenous. However, the latter is not surprising as the majority of interviews were conducted with researchers at only one institute (TERI).

The average number of connections per map and concept are highest among the local service providers. The same counts for average density, which is a measure for connectivity. It is lowest among planners and professionals, indicating a rather under-elaborated network and less complex understanding.

This is supported by the number of emitter (or 'transmitter' in Özesmi and Özesmi 2004) and receiver variables, which are measures for the strength of outgoing and incoming forces of a variable. Professionals show the highest number of both receivers per map and number of factors, and therefore have mentioned more outcomes and implications.

On the other hand, local service providers and researchers indicate more emitters, which translate into high numbers of causes for after-effects following rain events. In our case, this stands for higher complexity, as more forcing functions and additional influences are provided.

3.3.3 Cognitive Interpretation Diagrams: Statistical Analyses

As a result of the aggregation we get five CID maps, one for each stakeholder group representing its collective understanding. Table 3.3 summarizes the network statistics.

Table 3.3 Network statistics of the cognitive interpretation diagrams

New Delhi – Strong rain	Planners	Local service providers	Professionals	Researchers	Students
Size of maps					
Number of maps aggregated	7	26	13	7	14
Number of factors in CID	47	87	78	38	69
New factors/ map in average	6.71	3.35	6.00	5.43	4.93
Density of map					
Number of connections in CID	67	185	148	60	133
New connections/ maps in average	9.57	7.12	11.38	8.57	9.50
Average density [C/N(N − 1)] in CID	0.031	0.025	0.025	0.043	0.028
Complexity – influence diversity					
Number of receivers in CID	19	35	24	13	28
New receivers/maps in average	2.71	1.35	1.85	1.86	2.00
Number of emitters in CID	1	6	2	2	1
New emitters/maps in average	0.14	0.23	0.15	0.29	0.07
Receiver/emitter in CID	19.00	5.83	12.00	6.50	28.00

Table 3.3 shows that the CID of local service providers has the highest number of factors, which is understandable as a large number of single maps could be used. On average, however, only little more than three new factors were contributed per map, while, e.g., the planners added on average more than six new factors with each interview. A decrease in new factors with increasing interviews is in line with the theory (e.g. Özesmi and Özesmi 2004) as the graphical representation of the analysed system approaches completeness. In terms of density, Table 3.3 documents a remarkable difference to the single maps, as the CID of the local service providers is one of the least dense. Here, the artefact of very small maps leading to high numbers in density is suppressed. The researchers' CID is now the densest, witnessing a more complex understanding and more options available for change. Concerning emitters, the earlier analysis is underlined as local service providers and researchers provide additional causes and specifications of the forcing variable of strong rain, and a more comprehensive picture of the conditions during rain events.

So far we have concentrated on the statistical network analysis. The following assessment of climate change impacts on local populations, the kind of factors mentioned, and the strength of influence between them are of equal importance. For a better overview, the mentioned impacts have been grouped into 11 issue areas:

climate parameters and its physical forms; water problems and security; traffic problems and mobility; human health; energy problems and security; food security and agriculture; changes in the way of life, behaviour, social issues; economy (personal and public); built environment, infrastructure, technology; public support functions; natural environment. Graphical representations of the CID of each stakeholder group are presented in Figs. 3.1–3.5. The size of the node represents the centrality of a factor (summation of the absolute values of a factor's indegree and outdegree).

Professionals indicate a strong and relative equal influence of strong rain events across almost all sectors. Compared to other maps, the impact on the natural environment is relatively more pronounced.

For planners the impact of strong rain events is dominated by traffic jams and water logging. Relative to other groups, the impact on the electricity sector and food security is perceived to be small.

Students see a strong detrimental factor in water logging. Traffic jams and improper drainage seem to cause large problems too, as do diseases. The impact on the electricity sector is perceived to be small.

The most remarkable feature of the perceived impacts of strong rain events on the local service providers is their economic loss. Many have the impacts on their business most pressingly in mind. All other sectors are impacted as well. Water logging is a big problem as already seen within the other stakeholder groups.

Researchers regard local flooding and traffic jams as the most severe impacts of strong rain events. Various other impacts on traffic are recalled, as well as consequences for the personal environment, human health and the economy. The researchers are the only stakeholder group that made a connection to the wider public support functions, here mentioned with 'queries of the public related to rain on rise'.

The size of the bubbles in Figs. 3.1, 3.2, 3.3, 3.4, and 3.5 can vary across maps, not only because the centrality and importance of a certain factor can change but also because the probability to 'see more connections' increases with larger numbers of interviewees (the maps become more dense, thereby increasing the probability for a factor's centrality to be high). Therefore, a visual comparison across maps has to be made with caution. One possibility to compare the maps of the different stakeholder groups is by looking at factors with highest centrality. Table 3.4 lists the three highest factors for each CID (excluding the first one, which is always 'strong rain' and an artefact of the research design).

Across all stakeholder groups, water logging and local flooding is perceived to be the biggest problem, with the resulting traffic jams being a major burden. Among professionals, planners, students, and researchers, diseases and water-borne diseases are mentioned often and rank either second or third. Only among the local service providers this is different; for them, the impact on their business is extremely worrisome.

As an illustration, we now look at the researchers' collective impact perception (CID) as their perception showed a profound and complex understanding of the situation during rain events. The outdegree and indegree indicators enable to detect those variables with a strong influence on others (Fig. 3.6) versus those that are impacted themselves by others variables (Fig. 3.7).

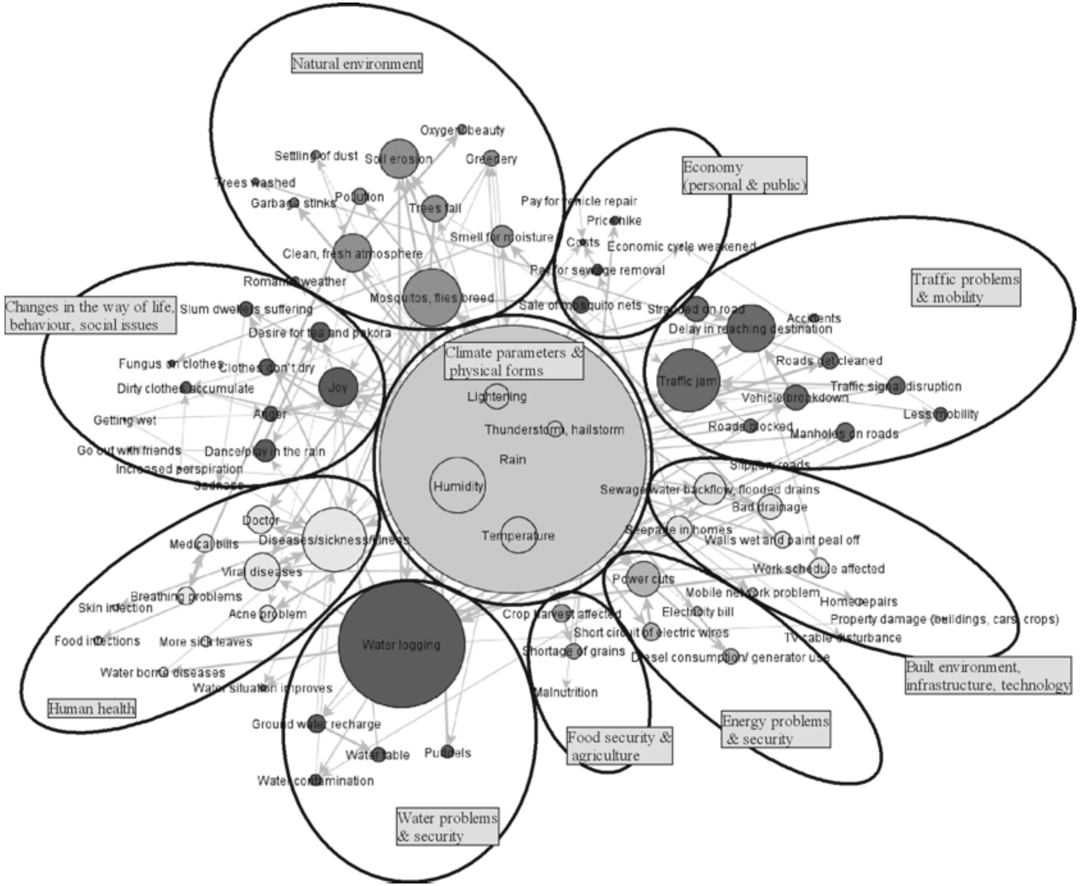

Fig. 3.1 Cognitive interpretation diagrams of professionals interviewed in New Delhi

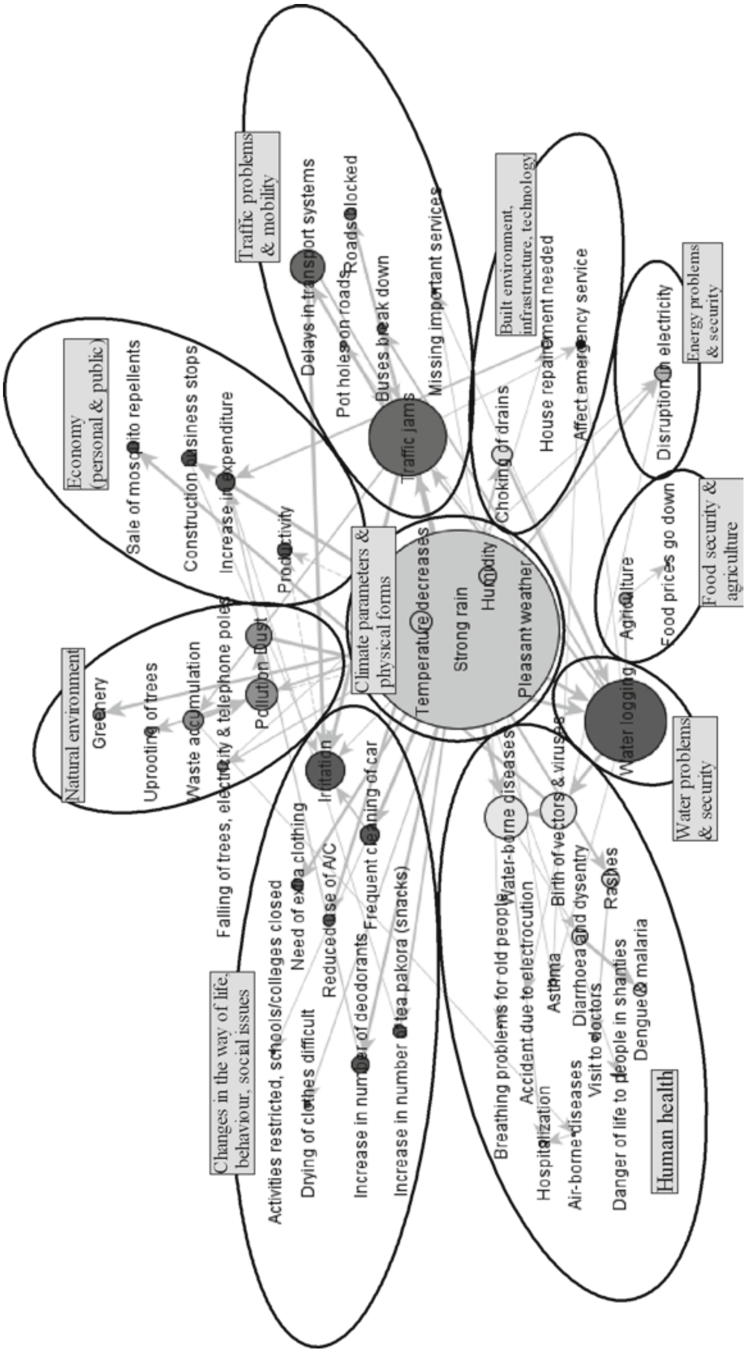

Fig. 3.2 Cognitive interpretation diagrams of planners interviewed in New Delhi

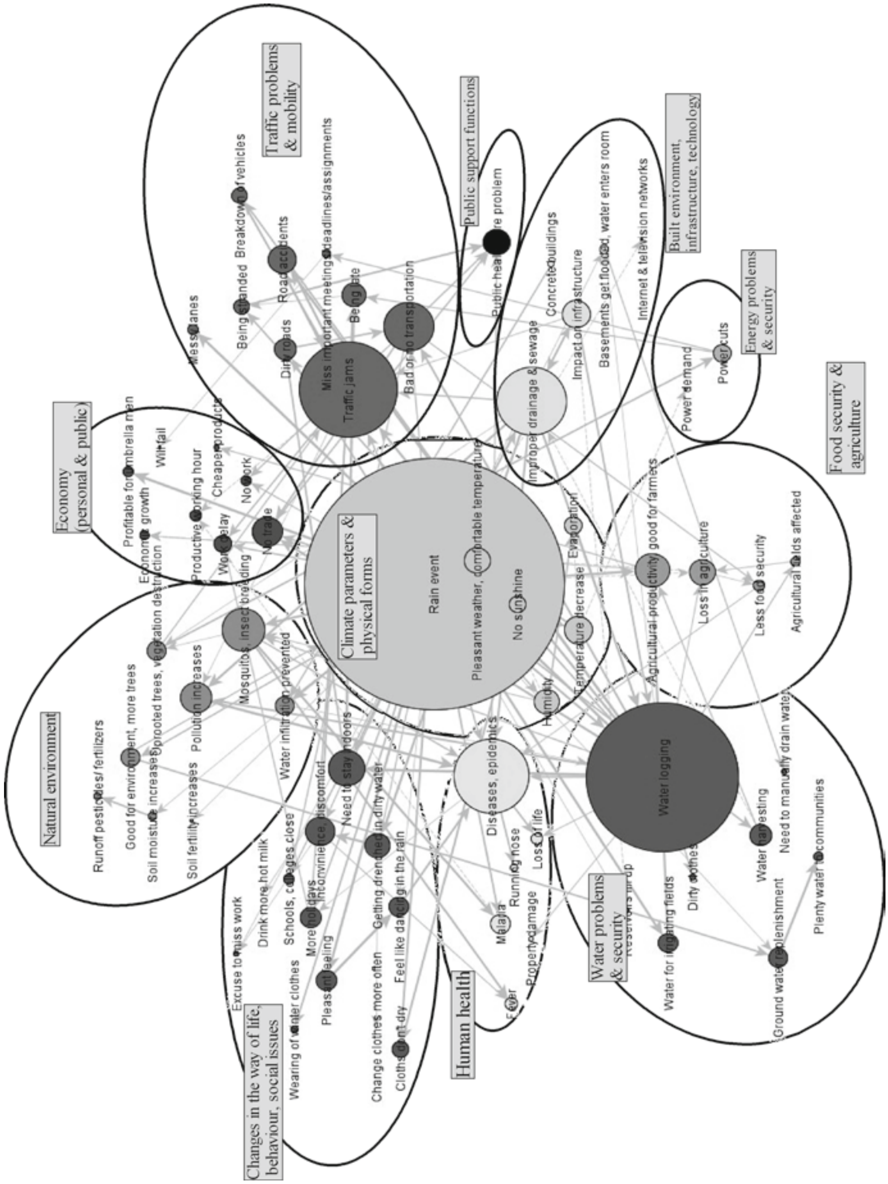

Fig. 3.3 Cognitive interpretation diagrams of students interviewed in New Delhi

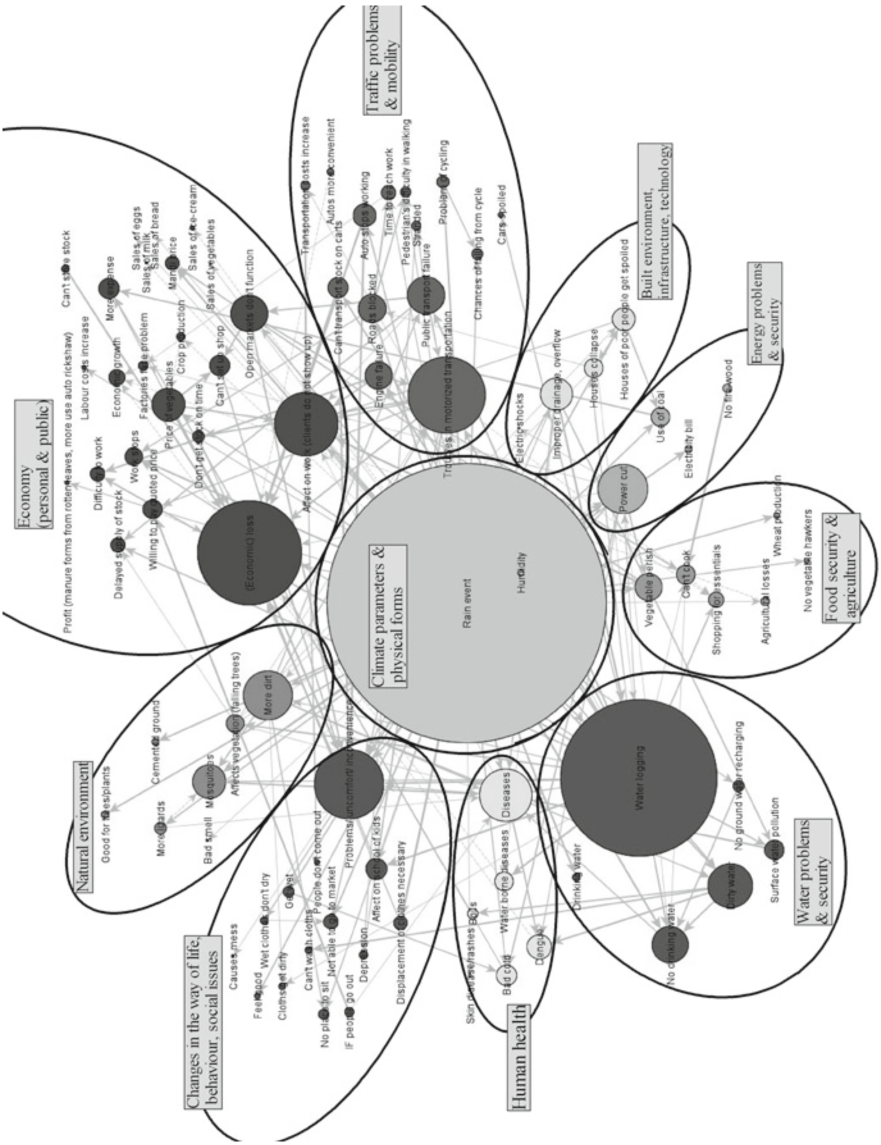

Fig. 3.4 Cognitive interpretation diagrams of local service providers interviewed in New Delhi

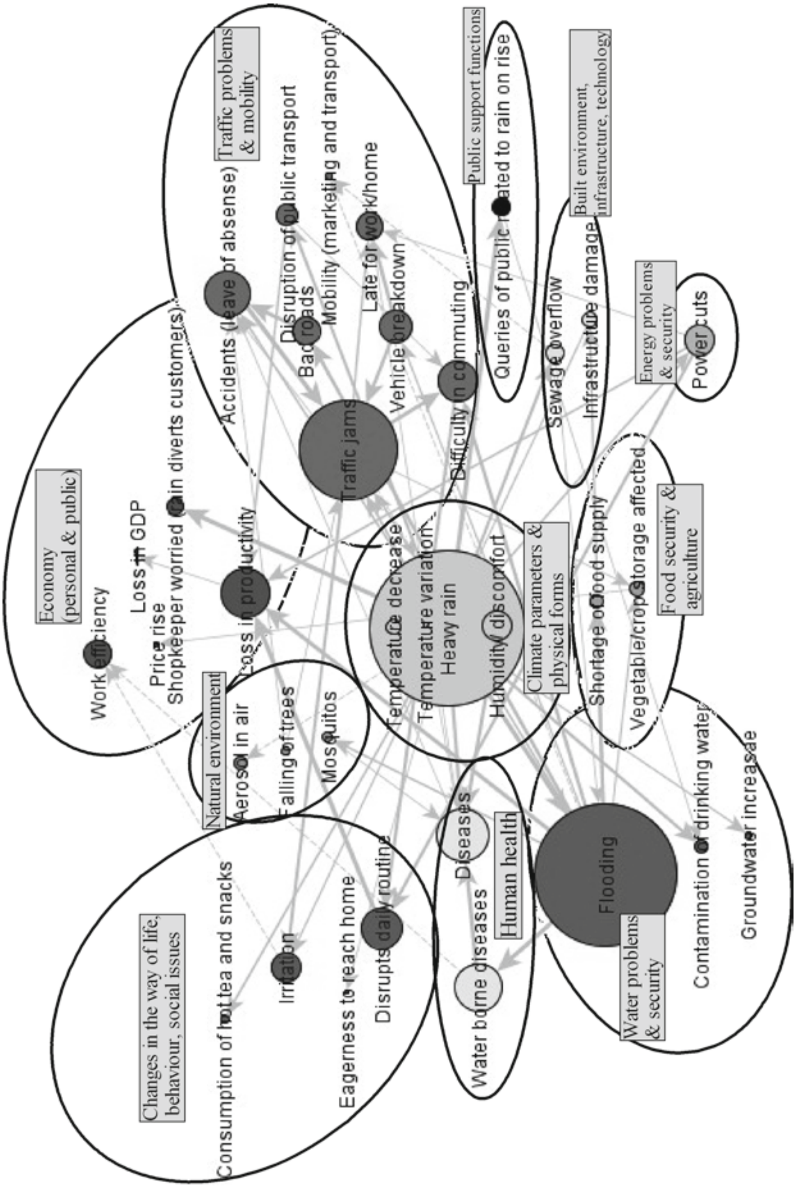

Fig. 3.5 Cognitive interpretation diagrams of researchers interviewed in New Delhi

Table 3.4 Comparison of factors with highest centrality across stakeholder groups

Professionals	Planners	Students	Local service providers	Researchers
Water logging	Water logging	Water logging	Water logging	Flooding
Diseases/sickness/ illness	Traffic jams	Traffic jams	(Economic) loss	Traffic jams
Traffic jam	Water-borne diseases	Diseases, epidemics	Troubles in motorized transportation	Diseases

Heavy rain has comprehensively the biggest outdegree of all factors. Local flooding and traffic jams are seen as significant issues too; water-borne diseases and humidity are also influential as are vehicle breakdowns and power cuts.

The factor 'traffic jams' has the highest indegree is the most strongly affected, which means that many aspects connected to strong rain are leading to traffic jams. Loss of productivity, diseases, accidents, difficulties in commuting and work efficiency are heavily impacted factors, too. In terms of adaptation, these findings suggest that local flooding, traffic jams and health issues are best addressed from a higher political level and through the planning departments. Since planners are aware and affected by those issues, they might address them more efficiently. On the other hand, finding solutions for the problems of the local service prodivders would probably best be addressed through a community approach or insurance coverage. We would argue that the planning levels cannot adequately address the concerns of the local service providers unless they first come to understand their concerns.

3.4 Scenarios

The matrices are semi-quantitative models of how a certain stakeholder or stakeholder group perceives its environment. By iteratively calculating the changes of the variable values caused by the incoming arrows, feedback loops in the system can play out, which enables the computation of the overall development of the system. By adjusting the values of certain variables, scenarios can be run (Wildenberg et al. 2010). Taking the system's understanding of the Delhi researchers as an example, we look at two scenarios: (1) assumes an increase in heavy rains and temperature variation, and a slight decrease in temperature after rain events, and (2) presupposes that these meteorological factors are met by some form of societal adaptation – the reduction in flooding. Table 3.5 shows the results. To compare the outcome of the scenarios look at the numbers in row five to seven. Higher numbers stand for an absolute increase and vice versa.

Table 3.5 shows that if a reduction of local flooding could be achieved, numerous factors in the map are simultaneously affected. Under the 'no adaptation' scenario, flooding, traffic jams, power cuts and disease would substantially increase, while under the 'adaptation scenario', traffic jams, water-borne diseases, shortage

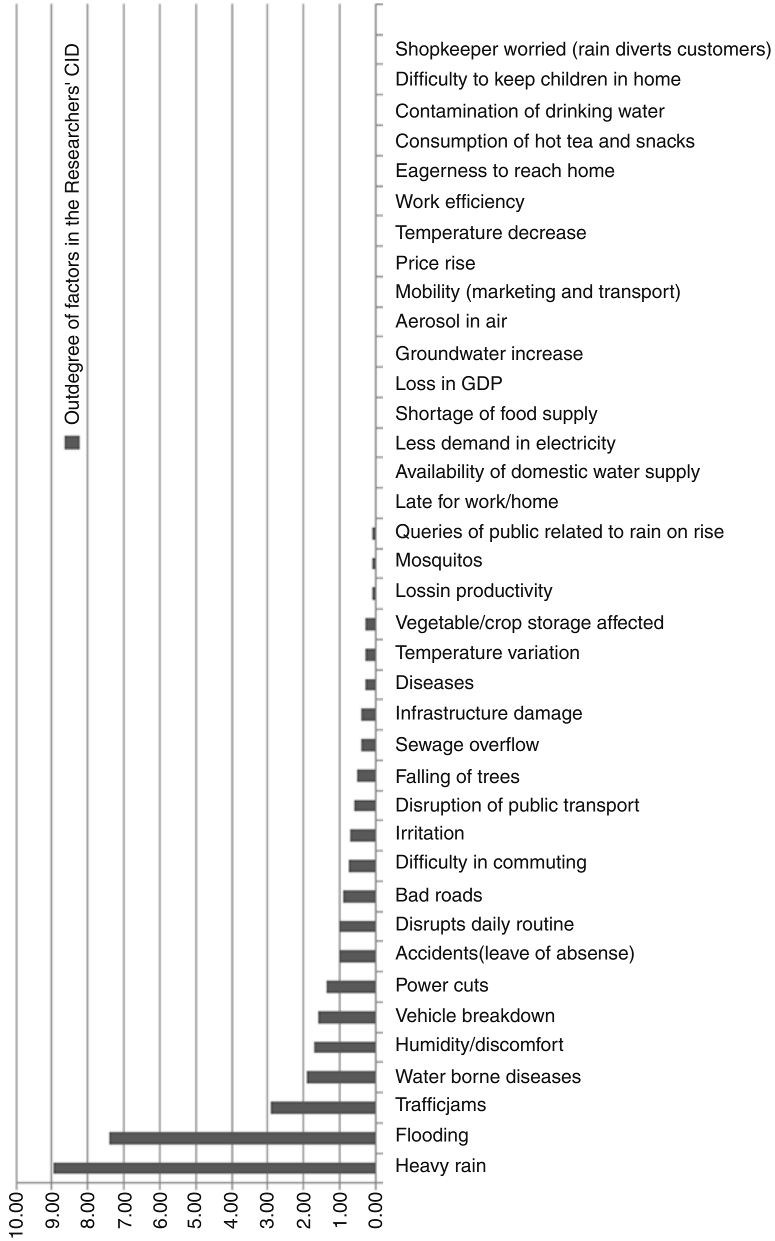

Fig. 3.6 Outdegree of all factors mentioned by researchers

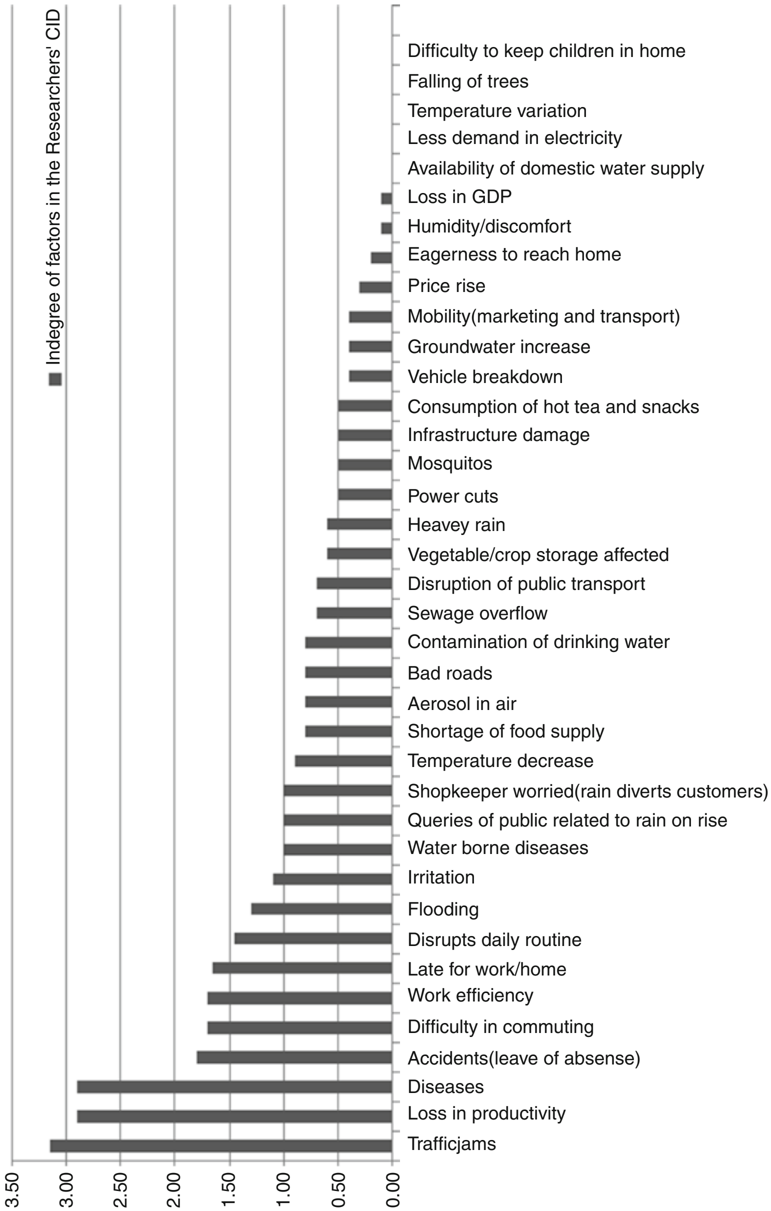

Fig. 3.7 Indegree of all factors mentioned by researchers

Table 3.5 Results of the scenario runs: climate change with and without adaptation

Concepts	No changes – scenario 1	Climate changes (CC) – scenario 2	CC and adaptation (CCA) – scenario 3	Results – no changes – scenario 1	Results – CC scenario 2	Change between scenario 2 and 1	Results – CCA scenario 3	Change between scenario 3 and 2
Flooding	1.000		0.000	0.632	0.769	0.136	0.000	–0.769
Vehicle breakdown	1.000			0.563	0.576	0.013	0.500	–0.076
Traffic jams	1.000			0.868	0.911	0.043	0.855	–0.056
Late for work/ home	1.000			0.756	0.767	0.011	0.750	–0.017
Power cuts	1.000			0.546	0.622	0.076	0.622	0.000
Water borne diseases	1.000			0.653	0.683	0.030	0.500	–0.183
Availability of domestic water supply	1.000			0.500	0.500	0.000	0.500	0.000
Less demand in electricity	1.000			0.500	0.500	0.000	0.500	0.000
Heavy rain	1.000	1.000	1.000	0.373	1.000	0.627	1.000	0.000
Humidity/ discomfort	1.000			0.509	0.525	0.016	0.525	0.000
Shortage of food supply	1.000			0.624	0.649	0.025	0.500	–0.149
Loss in productivity	1.000			0.864	0.889	0.024	0.797	–0.092
Loss in GDP	1.000			0.522	0.522	0.001	0.520	–0.002
Accidents (leave or absence)	1.000			0.759	0.777	0.018	0.673	–0.104
Sewage overflow	1.000			0.565	0.668	0.103	0.668	0.000

Groundwater increase	1.000			0.537	0.599	0.061	0.599	0.000
Aerosol in air	1.000			0.426	0.310	–0.116	0.310	0.000
Mobility (marketing and transport)	1.000			0.439	0.426	–0.013	0.483	0.057
Mosquitoes	1.000			0.578	0.595	0.017	0.500	–0.095
Diseases	1.000			0.818	0.900	0.082	0.883	–0.017
Temperature variation	1.000	1.000	1.000	0.500	1.000	0.500	1.000	0.000
Price rise	1.000			0.545	0.546	0.001	0.541	–0.006
Falling of trees	1.000			0.500	0.500	0.000	0.500	0.000
Vegetable/crop storage affected	1.000			0.605	0.620	0.015	0.543	–0.077
Temperature decrease	1.000	3.000	3.000	0.613	3.000	2.387	3.000	0.000
Irritation	1.000			0.698	0.706	0.008	0.690	–0.016
Bad roads	1.000			0.624	0.649	0.025	0.500	–0.149
Infrastructure damage	1.000			0.578	0.595	0.017	0.500	–0.095
Work efficiency	1.000			0.242	0.236	–0.006	0.272	0.037
Disruption of public transport	1.000			0.565	0.668	0.103	0.668	0.000
Disrupts daily routine	1.000			0.724	0.739	0.014	0.720	–0.018
Difficulty in commuting	1.000			0.778	0.804	0.025	0.679	–0.124

(continued)

Table 3.5 (continued)

Concepts	No changes – scenario 1	Climate changes (CC) – scenario 2	CC and adaptation (CCA) – scenario 3	Results – no changes – scenario 1	Results – CC scenario 2	Change between scenario 2 and 1	Results – CCA scenario 3	Change between scenario 3 and 2
Eagerness to reach home	1.000			0.519	0.550	0.031	0.550	0.000
Consumption of hot tea and snacks	1.000			0.546	0.622	0.076	0.622	0.000
Queries of public related to rain on rise	1.000			0.592	0.731	0.139	0.731	0.000
Contamination of drinking water	1.000			0.579	0.684	0.105	0.684	0.000
Difficulty to keep children in home	1.000			0.500	0.500	0.000	0.500	0.000
Shopkeeper worried (rain diverts customers)	1.000			0.592	0.731	0.139	0.731	0.000

Table 3.6 Factors most strongly altered comparing scenario 2 and 1: climate change against no changes scenario, and its qualitative interpretation

	Flooding increases	Heavy rain increases	Temperature variation increases	Temperature decrease after rain	Increasing queries of public related to rain on rise	Increase in worried shopkeeper (rain diverts customers)
Positive				↑		
Negative	↓	↓	↓		↓	↓

Table 3.7 Factors most strongly altered comparing scenario 3 and 2: climate change against climate change and adaptation scenario, and its qualitative interpretation

	Flooding reduced	Water borne diseases reduced	Shortage of food supply reduced	Accidents (leave or absence) reduced	Bad roads reduced	Difficulty in commuting reduced
Positive	↑	↑	↑	↑	↑	↑
Negative						

of food supply, accidents, bad roads, and difficulties in commuting decreases remarkably, while, e.g., mobility increases. Tables 3.6 and 3.7 give an overview of the six most affected factors and the qualitative direction of change when comparing the scenarios.

The analysis shows that investments in the drainage system and other measures to prevent flooding would substantially improve the living conditions of the Delhi inhabitants that we studied. Decreasing local flooding, as the first-order impact with highest outdegree, represents the best option for starting an efficient and comprehensive adaptation strategy. Reducing local flooding should therefore deserve adequate political attention and respective efforts by planning boards.

3.5 Conclusion

A fuzzy cognitive mapping approach was used to detect the impacts of strong rain events in a large urban residential area in New Delhi. It allowed individuals to draw impact nets and provided insight into the perceived seriousness of impacts on different people and stakeholder groups. The structure of impact nets were analysed for single maps as well as for stakeholder groups, i.e., planners, researchers, local entrepreneurs and service providers, students and (different other) professionals. Differences between stakeholder groups exist, i.e., the local service providers, in contrast to all other stakeholder groups, stress their fear of economic impacts after rain events. Local flooding and traffic jams are a concern for all, while health issues are worrying for some. Scenario runs comparing progressing climatic changes with and without adaptation measures to local flooding, yield and quantify the very benefit of the investment. Reducing local flooding, e.g., through the improvement of the drainage system and other measures, would substantially improve the living conditions of the New Delhi population. Reducing local flooding should therefore deserve adequate political attention and development priority by the New Delhi planning boards.

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Chapter 4
Assessment of Climate Change-Induced Vulnerability to Floods in Hyderabad, India, Using Remote Sensing Data

Oleksandr Kit, Matthias Lüdeke, and Diana Reckien

Abstract The frequency and intensity of extreme rainfall events over Hyderabad, India, are often the cause of devastating floods in its urban and peri-urban areas. This paper introduces a quantitative approach to assessing urban vulnerability to floods in Hyderabad, identifying informal settlements via high resolution satellite photography and through the development of a flood model for urban and peri-urban areas.

Keywords Flood modelling • India • Informal settlements • Lacunarity

4.1 Introduction

Projections for future climate patterns in South Asia suggest an increase in the frequency and scale of extreme precipitation events that will amplify the risk of significant urban floods. This is especially relevant to newly industrialised countries in the region, such as India, where cities play a crucial role in socio-economic development.

Hyderabad is one of the fastest growing cities in India. It is located in the north of South India and is the capital of Andhra Pradesh state. With a population of 5.5 million people in 2001, it is the sixth largest city in India (Census of India 2001). The Municipal Corporation of Hyderabad, the city's local government body, has calculated future population scenarios for Hyderabad and estimate that the 6.5 million people that lived in the jurisdiction of the Hyderabad Urban Development Authority in 2005 will grow to 7.7 million by 2011 and 10.8 million by 2021. The urban agglomeration may therefore be considered a megacity by around 2020,

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while scenarios for the wider urban agglomeration predict that by 2015 the 10 million mark will be crossed (MCH 2005).

The frequency and intensity of extreme rainfall events over Hyderabad, coupled with inadequate infrastructure and land use planning, often cause devastating floods in the city's urban and periurban areas. Hyderabad is a typical example of an emerging megacity where flood data are often unreliable, inconsistent or simply unavailable. Furthermore, there is little formalised information on the location and extent of the most exposed and vulnerable socio-economic entities, such as the densely populated informal settlements, which are not represented in urban development plans. In the following sections we discuss the methodology and results of a flood risk assessment in the city, combined with identification of informal settlements using lacunarity analysis of remote sensing data.

4.2 Flood Risk Assessment for Hyderabad

The potential hazards resulting from the flooding of Hyderabad as an inland urban agglomeration are high inflows via surface water and extreme local rainfall events. The river Musi, which traverses the city, has a relatively small upstream basin area (its source lies only 90 km to the west of Hyderabad) and is well regulated, posing a negligible threat presently and in the future. This, however, was not the case in 1908 when an extremely destructive flood hit the city. In response, the Osman Sagar and the Himayat Sagar dams were constructed, in 1920 and 1927 respectively. These reservoirs reliably prevent the city from flooding by the Musi and are major sources of drinking water.

The city is far less adapted to extremely intensive rainfalls which occur due to the monsoon precipitation regime and are expected to occur more frequently under future climate change. On the left hand ordinate of Fig. 4.1, we show the present distribution of daily rainfall at a sample station in the Hyderabad urban agglomeration (located at Begumpet, close to the former inner city airport). On the right hand ordinate, the expected change until 2100 is depicted under the A2 global CO_2-emission scenario (Nakićenović and Swart 2000). This shows a strong increase in the frequency of intense rainfall events (Lüdeke and Budde 2009)and along with the reported severe damages by strong rain events (Reckien et al. 2009), motivates further analysis of spatial and socio-economic vulnerability towards this kind of flooding. A clear indication that slum areas are most vulnerable is the August 2000 event in which 77 slums within the city area were completely washed away (IFRC 2000).

4.3 Identification of Flood Prone Areas

Low lying areas are frequently used as a first approximation for flood prone areas, e.g., in the context of sea level rise (Nicholls and Tol 2006). But this simple approach is inappropriate for assessing the impact of intensive rainfall events since

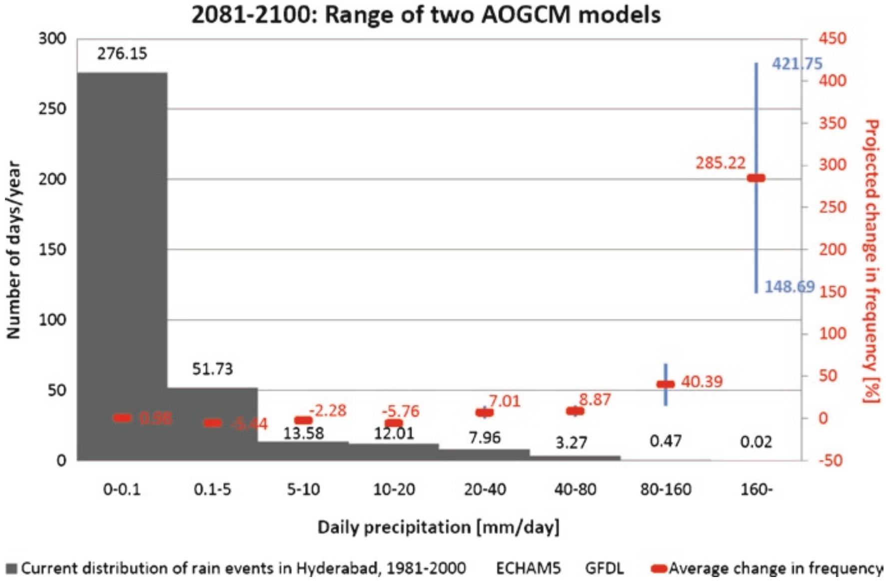

Fig. 4.1 Current distribution of daily rainfall (*left hand ordinate*) and expected change (*right hand ordinate*) for Hyderabad, India

rapid water flows generated at the surface can cause major damages, making a static analysis insufficient. On the other hand, a full hydrodynamic model that represents water flows and their momentum is very demanding with respect to the details of the orography and the spatial and temporal pattern of the rainfall events. As an intermediate step, then, we used a so-called flow accumulation map (Flacc, see e.g., Jenson and Domingue 1988) which describes the water flow at a particular location ('pixel') to be expected during a spatially homogenous strong rainfall event. This is calculated via the determination of the area of the upstream basin of the considered pixel; i.e., all locations are identified from where water flows to the considered pixel. From this it becomes clear that Flacc is a relative measure – the absolute amount of the flows depend on the rainfall intensity, but for any rain event, double Flacc means double water flow through the pixel.

As input data we used a digital elevation model derived from the latest available version of the Shuttle Radar Topographic Mission dataset (Jarvis et al. 2008) and dealt with noise and errors in the data in the order of 2 m by ignoring small orographic sinks that interrupt water flows artificially. After applying the respective algorithm to the digital elevation model for the Hyderabad agglomeration area we obtained a map that reproduced the natural surface waters (reservoirs and rivers) perfectly and, additionally, showed the net of water flows occurring under strong rain events (see Fig. 4.2). Comparison against the artificial sewerage and storm water channels network showed that some of the calculated flow paths are regulated while others are not. The flow accumulation map also identifies vulnerable areas along the clogged or encroached channels.

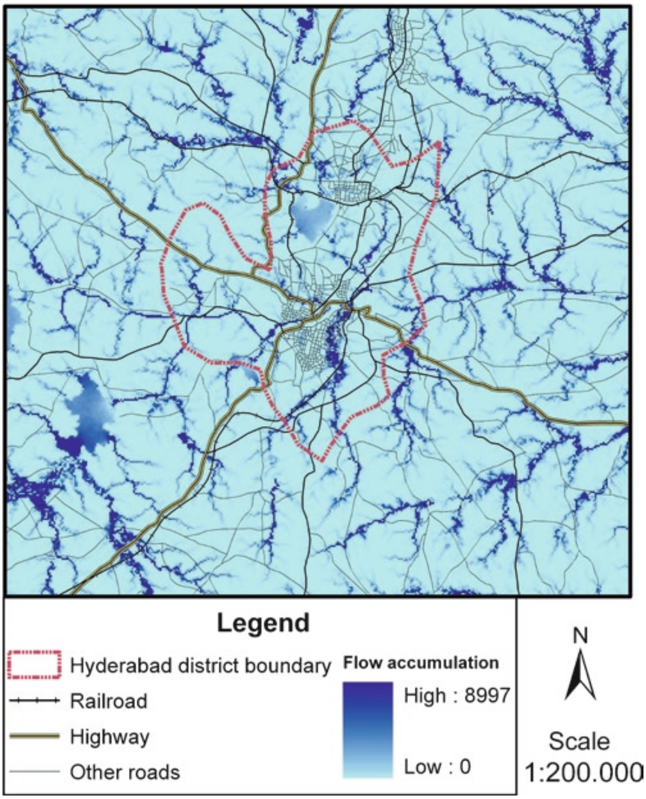

Fig. 4.2 Flow accumulation map for Hyderabad

4.4 Identification of Informal Settlements

Approximately 38% of Hyderabad's population is estimated to be living in informal settlements (MCH 2005), most being situated in rapidly growing outer municipalities. Confronted with high growth rates, urban planners and administrators in Hyderabad require up-to-date information on city-wide land use patterns. The informal and often temporary character of slums means that they are often difficult to track using ordinary methods. Remote sensing is a swift and unbiased technique of land use data acquisition, while the methodology proposed in this paper describes a promising data analysis technique capable of making qualified, spatially enabled statements on the location of informal settlements.

An informal settlement in India is often characterized as a 'compact area of poorly built congested tenements in an unhygienic environment usually with inadequate infrastructure and lacking proper sanitary and drinking water facilities' (Census of

India 2001). Such areas are frequently characterised by small dwelling units, narrow intrasettlement roads and high housing density – features that clearly distinguish them from other residential neighbourhoods and make remote sensing an appropriate data acquisition method for slum recognition.

There have been several attempts to perform informal settlement identification in India, and particularly in Hyderabad using spectral radiance values. Taubenböck et al. (2007) performed a land cover change study in Hyderabad using supervised classification techniques. While this approach was approximately 78% accurate in its recognition of built-up areas versus other land uses, the methodology was not capable of reliably distinguishing formal and informal settlements. Another study (Jain 2007) successfully used tonal variation in high spatial resolution data to identify rooftops within an isolated settlement. This approach, however, suffers from spectral noise and does not take into account morphological features of informal settlements.

The variability of materials used for roof construction in informal settlements and the extensive use of roofs for cloth drying or water storage equipment make identification of individual houses – a prerequisite of settlement density calculation in the Indian urban context – nearly impossible. A successful slum identification methodology must therefore take into account other surface properties, such as morphology and internal structure.

Cities can be viewed as complex systems composed of non-linear and multiple scale iterations of spatial and physical heterogeneous components (Amorim et al. 2009) and can thus be analysed by means of fractal mathematics. According to Gefen et al. (1983), lacunarity is a measure of the deviation of a geometric object, such as a fractal, from translational invariance, and as such is a suitable indicator to measure spatial heterogeneity. Since lacunarity values represent the distribution of gaps within an image at various scales, it is considered to be a promising tool for assessing urban structure and isolating distinctive morphological features.

Figure 4.3 schematically represents the algorithm used for identification of informal settlements in Hyderabad. Two sets of cloudless QuickBird high resolution remote sensing imagery (acquired in March 2008) were used in this study: image 1 which covers the 7.29 km^2 to the west of Hussain Sagar reservoir and contains Sanjeeviah Nagar slum has been used for algorithm calibration, while the equally large image 2 which covers the area to the east of Hussain Sagar is used for algorithm application and testing. First, principal component analysis was performed on the imagery, producing high contrast matrices, M_1 and $M_{2,}$ holding individual values stretching from 0 to 255 and clearly distinguishing between built areas and other land use types. Those matrices were then converted into binary datasets, $B_{48}{}^1$, $B_{50}{}^1$ and $B_{52}{}^1$, using 48%, 50% and 52% thresholds respectively. Each matrix has been further split into 100 × 100 pixel blocks (approximately 60 × 60 m^2 as per QuickBird resolution of 0.61 m). For each block the lacunarity value has been computed. We consider this box size to be an appropriate scale for identification of morphology of informal settlements as it accommodates fine scale intrasettlement structure, while leaving out large features that are more characteristic of industrial and formal residential areas.

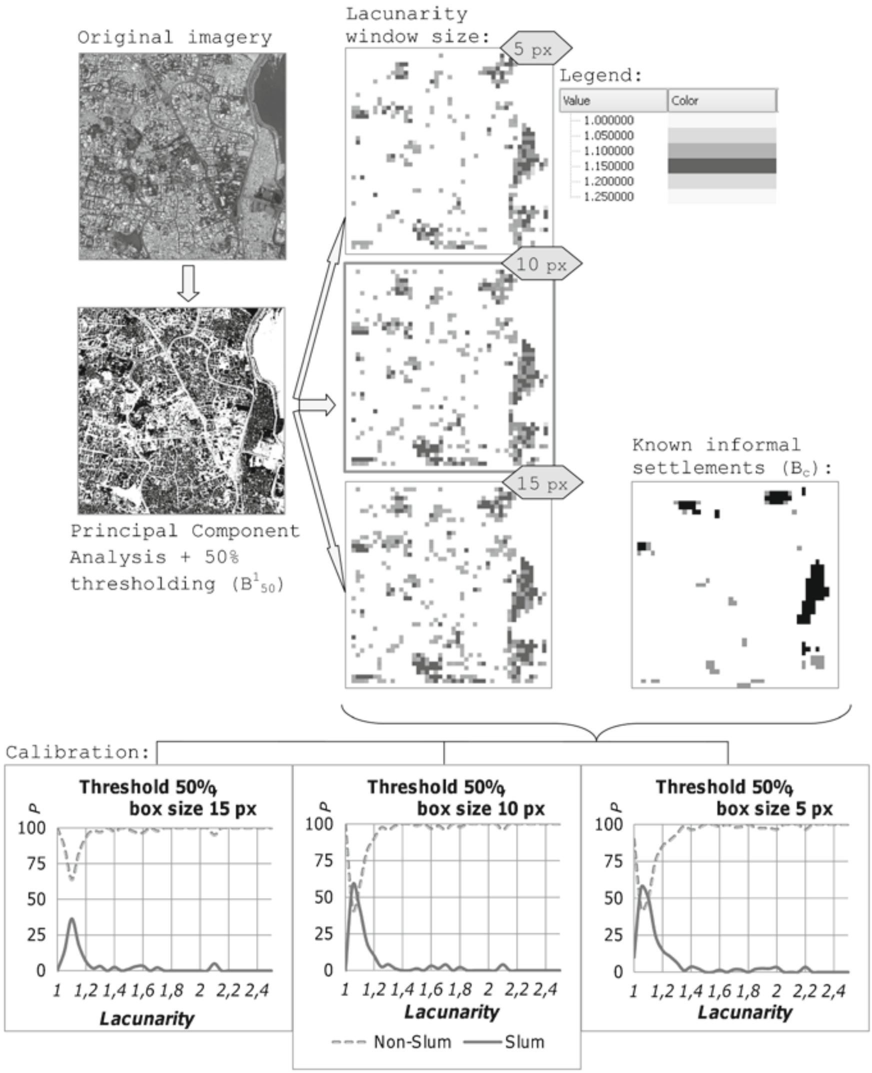

Fig. 4.3 Informal settlements detection algorithm and its calibration (for details see text)

Optimal moving window size has been empirically determined by calculating three lacunarity matrices for each binary matrix with moving window sizes 5, 10 and 15 pixels respectively (methodology adopted from Amazon forest classification by Malhi and Román-Cuesta 2008). Since the area covered by M_1 was relatively well-studied during fieldwork in Hyderabad in November 2009 and March 2010, it was possible to construct a binary calibration dataset, $B_{c,}^{1}$ which describes the location of informal settlements and all other areas. Using the B_c^1 dataset as a mask, it became possible to calculate probabilities of each lacunarity in matrices B_{48}^{1}–B_{52}^{1} to belong to slum or non-slum class (Fig. 4.3, bottom charts) and to conclude that the combination of 50% binarisation threshold and 10 pixel moving window sizes are optimal parameters for plausible identification of informal settlements in Hyderabad. This result is consistent with a previous study in this field (Barros Filho and Sobreira 2008), which showed that high spatial resolution satellite images from urban areas with better habitability have higher lacunarity values than those with worse conditions.

The empirically calibrated lacunarity calculation parameters were then applied to B_{50}^{2} matrix, which was the 'unknown territory' for the algorithm. As illustrated by Figs. 4.4 and 4.5, the algorithm has identified a large area of low lacunarity values in the upper left corner of the area of interest. Closer examination of the high resolution satellite imagery and analysis of ground truth data (Fig. 4.4) have revealed that the identified area does indeed belong to a high-density settlement known locally as Bholakpur slum.

Since the suggested methodology requires intensive computing power, the calculated spatial distribution of informal settlements in Hyderabad has not yet been applied to the city's whole urban area. Once this is carried out, the results should help refine spatially undetermined official figures and greatly assist the planning and management processes in the city.

Fig. 4.4 Validation of slum detection algorithm for Hyderabad (Photograph by Martin Budde/PIK)

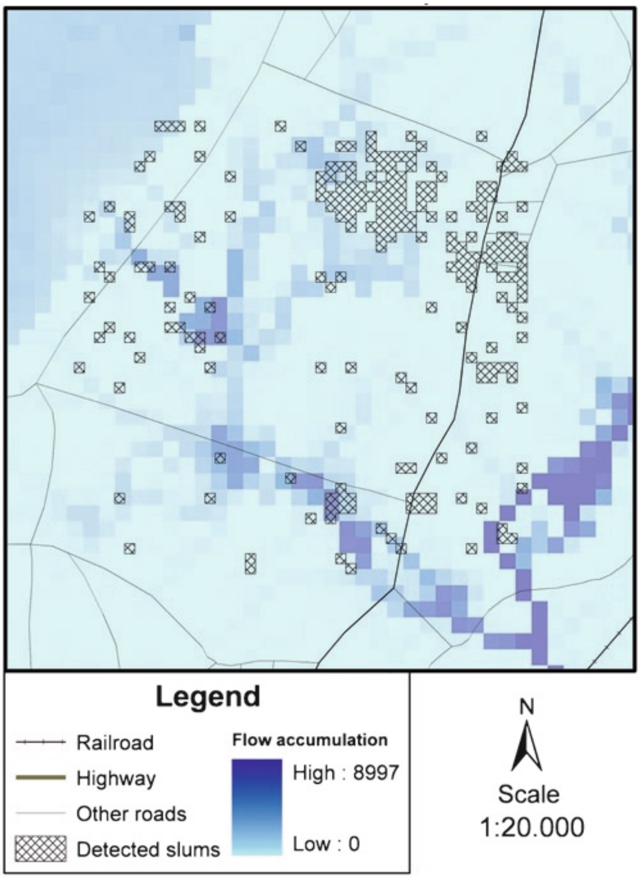

Fig. 4.5 Vulnerability of informal settlements to floods in Hyderabad

4.5 Conclusions

The comparison of flow accumulation maps with slum locations indicate high vulnerability to floods where informal settlements overlap with flow concentration areas. The Bholakpur slum's proneness to flooding, as detected on the informal settlements map in Fig. 4.5 (large red area in the upper part of the map), can be assessed as relatively low and can certainly be further reduced by appropriate urban planning and engineering measures. However, risk of flooding (hence vulnerability) is significantly higher in the informal settlements along the Hussain Sagar surplus drainage channel and Ashok Nagar Road in the Chikkadpally neighbourhood (approximately 0.02 km^2 area in the lower central part of the Fig. 4.5). This claim has been verified by visual examination of the satellite photography that revealed distinctive high density settlements on the banks of the drainage channel. As the frequency of extreme precipitation events in Hyderabad increases, so does the risk of increased water flow through the Hussain Sagar surplus drainage channel, which endangers the long term survival of weak informal structures on its banks if no flood defence infrastructure is in place.

This result illustrates how the methodology developed in this paper can successfully identify hotspots of climate change vulnerability on the basis of satellite based, globally available data sets. The calibration of the slum area identification algorithm requires additional knowledge of a small subarea of the urban agglomeration that includes known slum- and non-slum areas (B_c^1 in Fig. 4.3). It is quite possible that the calibration for Hyderabad also works for other Indian (or even developing world) urban agglomerations, but this will become clear during further applications. In our opinion, an important property of the suggested approach is its immediate transferability to other large urban agglomerations of the developing world that lack reliable large scale ground data.

Our first results corroborate the general claim that slums are often located in rainwater accumulation areas and frequently lack appropriate flood defence and rainwater drainage infrastructure. More importantly, it is possible to detect which slum areas will be most endangered by climate change and which will require the most attention with respect to adaptation measures. Along the basic dimensions of adaptation to climate change, 'accommodate – protect – retreat – avoid', the avoidance of new informal settlements in endangered areas is one of the most important options as slum areas rapidly grow. This demands a better understanding of where and why new slums occur. Applying the presented slum area identification algorithm to past time slices of satellite imagery will constitute a time series of the spatial slum distribution and allow for the development and testing of causal hypothesis of slum formation. This empirically tested understanding could be used to prevent the establishment of informal settlements in unfit locations while revealing superior settlement alternatives.

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Chapter 5
The Role of Community Resilience in Adaptation to Climate Change: The Urban Poor in Jakarta, Indonesia

Mario Wilhelm

Abstract Megacities are particularly vulnerable to the future challenges of population growth and climate change. The majority of people living in megacities are poor and reside within slums. Rather than seeing slums as a problem, though, this paper suggests that they be considered as a solution to the challenges arising from mega-urban complexity. Results based on a case study of Jakarta show that the urban poor have developed forms of resilience that are mainly based on collective action, or so-called *social capital*. At the same time, empirical data show that technocratic approaches to urban planning are unable to keep up with the dynamic nature of urban sprawl. Instead of increasing the transfer of expert knowledge and technology to megacities, this paper suggests that urban planning should start from solutions already developed on the ground. Promoting a citizen perspective might also be more efficient in economic terms.

Keywords Climate change • Adaptation • Jakarta • Megacity • Slum • Urban planning

5.1 Future Challenges in Megacities: Population Growth, Slums and Climate Change

Megacities are often the political and cultural centres of nation states, integrated into the global economy and at the heart of national innovation and economic growth. Yet megacities face a diverse set of challenges, most notably in relation

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to population growth and environmental hazards. Most megacities are located in low-lying coastal areas, locations that increase their exposure to disaster risk such as flooding and tropical cyclones. The debate over climate change indicates that extreme events will remain a serious challenge to megacities. High concentrations of people and economic assets further contribute to the high vulnerability of megacities to disasters (De Sherbinin et al. 2007: 39; IPCC 2001: 421).

Poverty is seen as a factor contributing to the social vulnerability of people living in megacities. The majority of megacities are located in developing countries (UN 2004: 84), which generally tend to show a limited capacity to cope with disaster risk (IPCC 2001: 441). The vulnerability perspective on megacities is made more complex when we look at the different vulnerabilities across the social strata in a megacity. It is widely acknowledged that the urban poor are most vulnerable to disaster risk and the negative effects of climate change. Since slums are regarded as the physical manifestation of urban poverty, they are of particular interest in the discussion of megacities and climate change. At first glance, the vulnerability of slum dwellers to disaster risk is obvious. Slums usually develop in locations that are highly exposed to hazard risks, such as in coastal areas, along railway tracks or on riverbanks. Moreover, slum dwellers often lack the financial assets to adjust and to cope with hazard risks appropriately. Slum dwellers, for instance, are often unable to invest in standard housing or to built-up financial reserves (De Sherbinin et al. 2007: 40; Adger 2003: 388; Bankoff 2003: 91–92). But not only will climate change present a future challenge to megacities. It is expected that future population growth will be largely concentrated in developing countries and that the additional population will be mainly absorbed by urban areas (UN 2004). Davis (2007) claims that future population growth will be largely absorbed by slums. Accordingly, megacities will transform into 'hypercities' and a large part of the world population will live in slums ('planet of slums').

Bringing these dynamics together signals a rather apocalyptic scenario for the future of megacities. Not only will vulnerable city dwellers be negatively affected by climate change, but the number of those vulnerable will also increase. While few would dispute that climate change exists, controversy remains over its future impacts. This uncertainty is a challenge to municipalities, city planners and other stakeholders who would like to adapt their cities to climate change. One way to approach this complexity is to learn from the mitigation and adaptation strategies on which city dwellers are presently reliant. By drawing on the case study of Jakarta, this paper aims to provide insights into community resilience in slums and how these findings could contribute to a rethinking of climate change adaptation on a municipal level.

The following section addresses the question of whether slums are a problem or solution to the challenges arising from mega-urban complexity. Section 5.3 follows with a general discussion of the empirical findings from a study on the urban poor in Jakarta. Section 5.4 concludes by suggesting further issues for debate.

5.2 Slums: Problem or Solution?

The dynamics described above require municipal leaders to act. Since urban planners often base their actions on the latest developments in urban research, the scientific community can have an important influence in urban planning. Korff and Rothfuß (2009: 355–356) summarize the status-quo research on megacities and state that 'most research on megacities focuses on Cassandra-like warnings of a coming apocalypse and mainly neglects the identification of solutions that have already been created.' Accordingly, they suggest two dichotomous urban trajectories in megacity research. The first trajectory accentuates the observed limits of governance, planning, technologies and integration in megacities. Through this perspective, the solution to 'urban catastrophe' involves improving urban planning, for example, transferring expert knowledge and the latest technology into cities.

The second trajectory acknowledges that cities of a certain size are 'ungovernable' (Mertins and Kraas 2008) and beyond 'plannability' (Korff 2008). Korff and Rohtfuß state that a megacity can hardly be planned, since urban sprawl rarely follows the outlines of technocratic urban planning. Through this perspective, the city cannot be regarded as a self-contained system following instrumental rationalities, but rather as a human settlement structured by the everyday life practices of its citizens; proven structures and processes developed by people have to be seen as a solution. It is therefore obvious that the challenges imposed on a megacity cannot be solved by following instrumental rationality, but rather by shifting the perspective from experts to the everyday life practices of the citizens. This 'citizen perspective' requires a permanent negotiation process between different actors in the urban context, such as citizens, the municipal government and city planners. Accordingly, urban planning should not be understood as a technocratic planning process that follows a top-down approach, but rather as a tool supporting and structuring the negotiation process of different actors (Korff and Rothfuß 2009: 356–361).

Brugmann (2010: 107) points in a similar direction by claiming that citysystems 'grow organically' and are the 'historical product of trial-and-error by a community of users.' From Brugmann's point of view, the citysystem is 'the most potent way to build a city to gain strategic advantage in an urbanizing world because it is the product of a community, rich or poor, that has mastered a very robust practice of urbanism.' Accordingly, citysystems do not generally follow master plans, but are instead a product of the spatial practices of city dwellers.

Following the citizen – or citysystem – perspective requires that we look into the everyday life practices that shape the citysystem. Since slums are home to the majority of megacity dwellers, thereby contributing significantly to the organic growth of cities, understanding their role in adaptation to hazards and climate change is crucial. However, it is difficult to open a balanced discussion on slums, since the term often has such negative connotations. The informal sector, in which most slum dwellers are employed, is seen by some scholars as something 'parasitic' that is opposed to modernization (see Lloyd 1979: 30). Todaro (1969) has suggested that migrants initially gain a foothold in the 'urban traditional sector' before moving into the 'modern sector.' In this view, slums are only seen as a temporary phenomena, since the informal sector is preparing the urban poor for advancement into the formal sector. Davis (2007), however, criticizes the assumption of upward mobility within the informal sector and suggests instead a 'down staircase', which leads into the black economy. He also suggests that the urban informal sector may be a dead-end street, resulting in the revolt of the urban poor in which the great slums are 'a volcano waiting to erupt' (Davis 2007: 201).

UN-Habitat (2003: 10) states that these negative connotations have damaging consequences. The stigmatization of slums provokes repressive action, such as slum clearance. In order to open the slum discussion, other scholars suggest that slums should be seen as an integral part of the citysystem. Drawing from his findings on a slum in Bandung/Indonesia, Barker (2009: 71–72) rejects Davis' hypothesis. He observed that slum dwellers are not left alone in informality, but are rather closely connected to state authorities. This connection is not only established through the formal bureaucratic system but also through close informal ties between state authorities and slum leaders. On a more conceptual level, Korff (1996: 293) concludes that the formal and informal sector are not opposed sectors but rather complementary. Economic growth, in his view, does not only increase the number of middle class jobs but also trickles down to the informal sector. On the one hand, a growing middle class requires more services from the informal sector, such as maids, drivers, guards or cleaners. On the other hand, the availability of cheap labor attracts investment. Slums are an integral part of modernization and economic development, since they offer comparatively cheap goods and services to the middle class. They also create a positive investment climate, since they have a direct influence on the cost advantages of the city. In addition to that, Barros and Sobreira (2002: 9) point out the important role of spontaneous settlements in the urban housing situation. By offering alternative forms of housing, spontaneous settlements cushion the housing deficit and thus contribute to the social stability of the city system.

Furthermore, one should realize that slums are not only functionally integrated into the citysystem. Slum dwellers find innovative and creative solutions to organize their everyday life in an environment that, at first glance, appears to be 'chaotic' and 'unorganized' (Korff 2009: 3; Korff and Rothfuß 2009: 364; Lloyd 1979: 29). In slum areas, the municipal government is often not able (or willing) to make resources available, such as basic infrastructure. In the absence of government schemes, slum communities often take collective action to improve the infrastructure, such as straightening and leveling streets (Lloyd 1979: 211). It can also be observed that security is often collectively organized and that social networks enable access to information beyond the slum, such as information on job opportunities (Korff 2009: 6). These examples indicate that slum dwellers have to develop a sense of community as a survival strategy. In many cases these communities show a high degree of self-organization, self-regulation and self-reliance.

Finally, we might conclude that the term *slum* is not appropriate to describe urban localities in which the majority of people are considered poor. If we leave the theoretical discussion and consider specific megacities, we will find that these localities are diverse and unique. These particularities are reflected in individual names, such as the *favela* in Rio, the *gecekondu* in Istanbul and the *kampung* in Jakarta. In each of these cities, everyday life practices evolve to meet challenges. Characterizing slums as a solution, of course, is not to provide a romantic description of everyday life in megacities, but it does point to the double-edged nature of slums. Korff and Rothfuß (2009: 360) emphasize this point: '[o]n the one hand, it is essential to understand that slums are centers of poverty, criminality and ecological problems. On the other hand, they are centres where practical solutions are developed'. Accordingly, it might be worthwhile to change the approach to mega-urban challenges by starting with solutions that enable slum dwellers – and mega-urban citizens generally – to mitigate and adapt to risks.

5.3 Jakarta: Adaptation at the Local Level

Jakarta serves as a wonderful example to illustrate the theoretical discussion above.[1] The Indonesian capital city was established by the Dutch as a colonial trading base in 1619. Over time the city transformed into a megacity of around nine million inhabitants (as of 2004) and is part of a mega-urban region of 24 million people. The strategic location that once made the city a prospering harbor town is today the major reason for floods. Located close to the sea, large parts of Jakarta are low-lying areas and are easily flooded during high tide or after major rainfall, since the water run-off cannot easily discharge into the sea. In 2007, floods covered 70% of the city area, displacing 400,000 people. The reasons for the flooding are numerous and range from excessive ground water tapping in the city to redevelopment in up-stream areas. Since most of the reasons are directly linked to urbanization, it is expected that urban dynamics will aggravate the flood situation in the future. In addition, a natural astronomic cycle is expected to have an impact on tides and sea levels. Over the coming years, the sea level in Jakarta will rise by another 80–100 cm and reach its peak on December 6,2025. At this time, higher sea level together with land subsidence will result in the permanent flooding of a strip that spreads 5 km from the coast into the city. It is important to note that this prediction made by hydrologists does not include scenarios on the adverse impacts of climate change.

Given the unfavorable location, it is not surprising that flood risk was taken into consideration in urban planning when the city was founded in the seventeenth century. However, urban planning could not keep pace with the rapid urbanization dynamics of the twentieth century. In 2002, for instance, the flood management control system being implemented was still in line with the late colonial flood control plans from 1920. Today, urban planners realize that spatial planning cannot

[1] The data presented here was collected as part of field research in Jakarta. For more information, see Wilhelm (2009, 2010).

stop the flood situation from getting worse, and that while technical engineering may reduce floods, Jakarta will never be flood free. Accordingly, new forms of direct citizen involvement in flood management are being discussed, such as community involvement in early warning and shifting funds to the lowest level of administration in order to guarantee fast flood response.

Regardless of the future consequences of climate change, the municipal government, urban planners and citizens of Jakarta are already facing the need to develop flood mitigation strategies and adaptation strategies to rising sea levels. This present challenge draws the attention to the mitigation and adaptation strategies that are already in place. The majority of people in Jakarta, around 60–70% of the city dwellers, live in so-called kampungs. Kampungs originally referred to the homes of the ‘native’ population in the colonial city of Batavia. However, in the course of rapid urbanization kampungs became subject to land speculation and finally eviction. Today, remaining kampungs in the inner-city are often stigmatized as slums, since they are densely populated and can contain sub-standard housing as well as a lack of basic infrastructure. Most kampungs are concentrated in hazardous locations, such as flood prone areas along the major canals or on the river banks. Still, it is surprising to learn that not only ‘poor’ migrants reside in kampungs. Workers and employees working in the low-income segment of the formal sector also choose to live in kampungs. The reason for that is the range of opportunities kampungs are offering to their inhabitants. Due to the strategic location in the inner-city areas, people can cut transportation cost and commuting time to their place of work. Moreover, living costs in kampungs are affordable for low-income households, since food is relatively cheap and cost of housing is manageable. In comparison with rural areas, people also mention access to education and health care as further advantages of living in urban kampungs.

Although kampung dwellers generally lack financial resources, empirical data suggests that they have succeeded in adapting to a changing environment. Through community and neighborhood organizations (RW/RT-system) kampung dwellers not only pool and organize the scarce resources they have, they also establish networks with external parties. In the context of floods, it is also surprising to learn that kampung dwellers developed a kind of informal warning system that is based on communication structures with municipality employees at flood gates or with relatives/friends in up-stream areas. The formal information chain in flood warnings is bridged so that people must not rely on the well established, but time consuming and sometimes unreliable, formal communication structures. Additionally, buildings are usually adapted to the flood situation. In the case of flood warnings, people move their valuables to the second floor of their two-story homes. Flood procedures appear to be institutionalized; people know where to evacuate, neighborhoods establish a security system to prevent looting, and resources are pooled so that the evacuees have access to food and water.

With persistent floods, loss of the daily earned income appears to be the major difficulty, since many people are employed in the informal sector. During flooding, kampung dwellers depend on external support – aid from the government, political parties, donations from business companies and private initiatives – to cover their basic needs. Through (often charismatic) leaders, kampung dwellers organize coping activities within the neighborhood. This allows kampung dwellers to articulate their interests to external parties and represent themselves as a bounded community. As floods recede, kampung dwellers return to their homes and are soon back to everyday life.

Kampung dwellers commonly state that they do not perceive floods as a serious problem, but rather as something ‘normal’ and part of everyday life. This is no surprise given the fact that kampung dwellers have learned to mitigate and adapt to the flood situation for several decades. While kampung dwellers may be classified as vulnerable in terms of income poverty and exposure to environmental hazards, they show forms of resilience that are mainly based on the capacity to act collectively. This so-called social capital rests within the community or neighborhood organizations and allows kampung dwellers to both organize the community and establish social networks with external parties.

5.4 Shifting to a Citizen Perspective in Climate Change Adaptation

The findings from the inner-city kampungs in Jakarta and the general theoretical discussion on megacities, slums and climate change, suggest that urban slums form an integral part of the megacity. The empirical data suggest that kampungs are anything but disorganized and chaotic. Due to the limited scope of municipal administration and the challenges of everyday life, kampung dwellers are compelled to form a sense of community. The result is a high degree of social cohesion, as well as robust forms of self-organization, self-regulation and self-reliance. Local resilience, then, is mainly based on social capital. This form of resilience translates into mitigation and adaptation strategies that can be applied in everyday life situations as well as in the context of external threats.

We might conclude that the kampung already represents a solution to many of the challenges faced by most city dwellers. The resilience perspective becomes even more important in light of the overwhelming urban sprawl that municipalities must manage. However, this conclusion does not suggests that kampung dwellers are resilient to future dynamics in general, such as climate change, nor does it suggest that technocratic approaches in urban planning are becoming obsolete. As slums absorb future population growth, the pressure on spatial and social structures will further increase. Moreover, the case study shows how kampung dwellers have developed a capacity to mitigate and adapt to floods by learning from past experience. The expected astronomical tide and possible adverse impacts of climate change might lead to a situation that requires new forms of mitigation and adaptation strategies. Urban planners will face limitations in their ability to simulate or model the scope of future urbanization and the impact of climate change. The municipality is currently facing difficulties in implementing flood control measures based on past flood control plans, and it may stand helpless in the face of future dynamics. However, it should be acknowledged that the citizen perspective is already taking hold in some urban expert circles. This can be observed, for instance, through the now fashionable use of such terms as 'social engineering' and 'multi-stakeholder approaches' (see United Nations University Press (UN) 2010).

We may now draw the following conclusions on the role of slums in climate change adaptation: First, because urban sprawl within megacities does not follow the master plans designed by urban planners, technocratic approaches to climate change adaptation should not be taken as a panacea; that is, the success of transferring expert knowledge and technologies should not be overestimated. Second, slums are an integral part of citysystems and represent the majority of dwellers within the megacities of developing countries. With respect to climate change adaptation, then, slums should not be dismissed or approached with hostile policies. Third, since citizens are constantly developing strategies that allow them to cope with the everyday life challenges of megacities, city leaders and urban planners might be well advised to base their climate change mitigation and adaptation strategies on the citizen perspective.

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Chapter 6
Ecohealth and Climate Change: Adaptation to Flooding Events in Riverside Secondary Cities, West Africa

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Abstract In 2009, for the first time in history, more people were found to live in urban areas than in rural settings. Predictions for 2025 are that 70% of the world's population will be urban. Urban dwellers in particular, then, will need to adapt to climate change. Urbanization occurs at a rapid pace in secondary cities across Africa. Indeed, half the increase of urban populations in the coming years is expected to occur in secondary cities. Poor settlements near water bodies (rivers, irrigation systems and large dams) are prone to flooding, which is likely to be exacerbated by climate change. Employing an ecohealth approach, this study explores the vulnerabilities and resilience of poor urban settlers in four secondary cities of West Africa, all located in close proximity to water bodies: Korhogo, Côte

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d'Ivoire (212,000 inhabitants, near a dam); Kaédi, Mauritania (71,000 inhabitants, near a river); Ziguinchor, Senegal (269,000 inhabitants, near a river); and Kara, Togo (120,000 inhabitants, near a river). The aim of this study is to reinforce the resilience of the most vulnerable of these communities and their capacity to adapt to processes of drought and flooding in two climatic contexts: semi-arid and tropical humid. Local governance authorities play a central role in this project, which emphasizes participatory research, and explores linkages between hazards, vulnerabilities and local adaptive capacity potentials, particularly in the water and health sectors.

Keywords Climate change • Ecohealth approach • Resilient cities • Water • West Africa

6.1 Background

Recent studies have reported high variability of rainfall pattern in West Africa (MBaye et al. 2004; Sylla et al. 2010) and an increasing frequency of extreme weather events in the region (PNUD 2007). Droughts and floodings represent more than 90% of all natural disasters in Africa (Douglas and Alam 2006; IDRC/CCAA 2008). Although droughts and floods, by definition, cannot occur simultaneously in the same location, they are observed more often in certain areas and at a certain periodicity, particularly in the Sahelian zone. In 2007, for example, floods occurred in 13 West African countries with more than 600,000 people affected, including Côte d'Ivoire, Mauritania, Senegal and Togo (UN 2007).

The 3-year project titled 'Ecohealth approach in the management of water and health in relation to climate change: adaptive strategies to drought processes and floods in four countries in West Africa' was approved in 2008 and commenced the following year (Cissé 2009; Koné et al. 2009). This project was part of the framework of a joint programme with the theme 'Climate change adaptation in Africa' (CCAA). The overarching objective of the project is to reinforce community capacity to adapt to processes of droughts and floods in two climatic contexts (semi-arid and tropical humid) of West Africa. The specific objectives are:

- to generate scientific data on the links between climate change, water resources management and health at community and national levels regarding environmental, economic, social, gender and sanitary aspects;
- to reinforce different actors' adaptation capacities (communities, researchers, decision makers, and non-governmental organizations (NGOs); and
- to establish a collaborative platform at the West Africa regional level between researchers and other stakeholders.

6.2 Literature Review

6.2.1 Africa's Need to Adapt to Climate Change

Africa has low institutional and financial capacities for adaptation to climate change (Pochat et al. 2006; Murgida and Nalenzon 2007; IDRC/CCAA 2008), yet there is a pressing need to address these issues (Douglas and Alam 2006; Confalonieri and Menne 2007; Kundzewicz et al. 2007; Parry et al. 2007; WHO 2009b). The climate sciences, by providing robust results derived from time-series analyses, have succeeded in convincing other actors of the need for adaptation to climate change. Adaptation has become a challenge for disciplines other than just the climate sciences. These challenges are particularly high in the water and health sectors (Niasse et al. 2004; PNUD 2007; Bates et al. 2008; WWAP 2009).

6.2.2 Adaptation to Climate Change: It's All About Water and Health

Climate change adaptation will mainly concern issues relating to water (Bates et al. 2008), and subsequently health (Gill and Stott 2009; Kovats 2010; Künzli 2010). Water scarcity is expected to deteriorate, worsening already inadequate sanitation and hygiene standards in the developing world. This, in turn, is likely to curb transmission of infectious diseases, such as diarrhoea and malaria (Hay et al. 2005; McMichael et al. 2006, 2009; Moore et al. 2008; WHO 2009b; WHO and UNICEF 2003). Water-related diseases, most notably malaria and schistosomiasis, may occur in cities and areas proximal to water networks, as the particular ecosystems surrounding these locations provide suitable conditions for *Anopheles* mosquitoes (malaria vectors) and snail intermediate hosts of schistosomiasis (Patz et al. 2005; Watson et al. 2005; Moore et al. 2008). It is estimated that by 2050, six billion people will be at risk of one or several of the 'big seven' climate-related diseases: malaria, dengue and other hemorrhagic fever viruses, schistosomiasis, human African trypanosomiasis, Chagas' disease, leishmaniasis, and onchocerciasis (Costello et al. 2009; Kjellstrom and Sauerborn 2009; WHO 2009b).

6.2.3 Rapid Increase of Urban Dwellers in Secondary Cities of Africa

In 1900, only 13% of the world's population lived in urban areas. Predictions for 2025 are that over 70% of the world's population will be urban (Potts 2009; WHO 2009a). It follows, then, that most people adapting to climate change in the future will be living in urban areas. Half of current urban dwellers live in cities or towns with fewer than 500,000 inhabitants (UNHabitat 2008a, b), and half of the increase in urban populations in the coming years is expected to be in urban settings of this size (Costello et al. 2009; Potts 2009; WHO 2009a). In Africa, the world's most rapidly urbanizing continent, profound urbanization dynamics are occuring; not only in the capital cities, but also in secondary cities, particularly those in close proximity to water networks such as rivers, man-made lakes and irrigation systems. Due to deficiencies in safe drinking water and basic sanitation infrastructure, poor urban dwellers living along major rivers or in peri-urban areas are exposed to a host of negative health effects. These may be further impacted by climate change (Hunt and Watkiss 2007; Satterthwaite et al. 2007; Carmin and Roberts 2009).

6.3 Methodology

6.3.1 Ecohealth Approach and Outcome Mapping

In order to manage the multi-hazard nature of climate risk and variability, an integrated approach is necessary in which different sectors work closely together (IDRC/CCAA 2008; Yang et al. 2010). Ecohealth approaches and systems thinking lend themselves well to address such challenges (Forget 1997; Lebel 2003; Cissé et al. 2008, Berrang-Ford et al. 2009; de Savigny and Adam 2009; Nguyen et al. 2009). For this reason we adopted an ecohealth approach, consisting of the following main pillars:

- looking at ecosystems at an appropriate scale and within defined borders;
- promoting participation of communities and other stakeholders;
- conducting transdisciplinary research on health at the interface of environment, economy and community – involving environmental scientists, geographers, socio-anthropologists, sanitary engineers, epidemiologists, public health experts, economists and climate scientists; and
- consideration of gender and equity dimensions at all stages of the process.

There is also the challenge of building a wide partnership engagement between different stakeholders from the local to the national level. Local authorities (i.e., mayors and municipal council members) in particular must give more attention to the concepts and projects related to adaptation to climate change. Participatory outcome mapping approaches are particularly useful (Jones and Hearn 2009), as they allow:

- assessment of the project's influence on behavioral change;
- thinking in terms of 'contribution' rather than 'attribution'; and
- moving from stakeholders to 'boundary partners and strategic partners'.

The outcome mapping tools are used to steer the implementation process, helping the project change behavior and guide strategic and boundary partners in translating key findings into action.

6.3.2 Integrated Climate Risk Assessment and Adaptation Framework

We adopted a framework that evaluates adaptation to climate change under three areas (Rosenzweig and Solecki 2001; Hallegate et al. 2008; Kinney et al. 2008; Gilbride and Rosenzweig 2009; Mehrotra et al. 2009), namely:

- hazards and risks;
- vulnerabilities; and
- adaptive capacity.

Vulnerable and adaptive capacities are linked to the concept of resilience. We embrace the concepts of vulnerability and resilience as relational and reciprocally linked. We understand vulnerability defined as a 'combination between the risks of exposure and the lack of adequate means to manage them' and resilience as 'the capacity to react to and manage or even prevent risks and shocks to which households, groups and communities are exposed' (Tanner and Mtasiwa 2002; Obrist 2006; Schneider et al. 2007; Sy et al. 2010).

In each location the research team reviewed readily available records in order to map existing datasets of time-series on temperature, rainfall, water resources (changes in availability and usage), burden of diseases, including emerging infectious diseases. Particular attention was given to the ecosystems (Fischlin et al. 2007; Rosenzweig and Hillel 2008) and factors playing a major role in the transmission of the major water-related diseases such as malaria and schistosomiasis (Yang et al. 2010). A kick-off workshop, exploratory visits by the research team and preliminary geographical and household surveys ensured that various stakeholders from local and national levels (particularly the country climate change focal point and representatives of the research and academic institutions) actively engaged in the project and data collection.

6.4 Preliminary Results on Climate Risk, Vulnerability and Adaptive Capacity

6.4.1 Characteristics of the Selected Secondary Cities

The study took place in four countries, targeting one secondary city in each country:

- Korhogo (Côte d'Ivoire);
- Kaédi (Mauritania);
- Kara (Togo); and
- Ziguinchor (Senegal).

Korhogo is located 650 km from Abidjan, Côte d'Ivoire's economic capital, and has an estimated population of 212,000 inhabitants. Kaédi is situated at 430 km from Nouakchott, the capital city of Mauritania, and has 71,000 inhabitants. Kara is located at 413 km from Lomé, Togo's capital, and the population is estimated at 120,000 inhabitants. Ziguinchor is at some 450 km north-east from Dakar and has 269,000 inhabitants. The four selected secondary cities are among the ten most populated cities in the respective countries and are characterized by close proximity to major water bodies. Kaédi is located along the Senegal River, Kara near the Kara River, Ziguinchor near the Casamance River and Korhogo has some settlements in close proximity to a man-made dam.

6.4.2 Hazards and Risks

The major climate-related risks to anticipate in the four selected secondary cities are as follows: floods and drought as a result of changing rainfall patterns, strong winds, coastal erosions, and heat waves (MDRE 2004; MEPN 2006; MERF 2009). For all cities, floods and droughts are predicted to play the dominant role among the extreme events.

The initial climate time-series data obtained for the four cities are covering different periods: Korhogo (1972–2000), Kara (1979–2008), Ziguinchor (1951–2008) and Kaédi (1968–2008). Table 6.1 shows the climate risk features for the respective cities. The data in Ziguinchor are illustrative of the trends regarding rainfall and temperature:

Table 6.1 Climate risk features in the four selected cities, West Africa

	Korhogo (Côte d'Ivoire)	Kara (Togo)	Ziguinchor (Senegal)	Kaédi (Mauritania)
Available time series	1972–2000 (precipitation)	1979–2008 (precipitation, temperature)	1951–2008 (precipitation)	1968–2008 (precipitation)
Dry season	November–April	November–April	October–June	October–June
Rainy season	May–October	May–October	June–October	June–October
Annual precipitation (mm)	1,300	1,400–1,600	1,478 mm (1951), 744 mm (2002), 1,600 mm/year at Oussouye (1931–1990), 1,200 mm/year (1961–1990)	350–400 mm (1970), 250 mm (2000)
Mean maximum temperature (°C)	30	38.7	32.3 (1951–1980); 34.6 (1981–2008)	38–40
Mean minimum temperature (°C)	23	17.9	19.4 (1951–1980); 20.6 (1981–2008)	25
Past flood events	2007	2007	Not determined	1995, 2002, 2007, 2009

the annual precipitation decreased from 1,478 mm in 1951 to 744 mm 50 years later. The average maximum temperature increased from 32.3°C in the period 1951–1980 to 34.6°C in the period 1981–2008. The working groups' sessions during the kick-off workshop confirmed the high variability of rainfall patterns and the more frequent occurrences of flooding events.

6.4.3 Vulnerabilities

In all four countries, the proportion of people living below the income poverty line (i.e., US$ 2 per capita per day) in the years 2000–2007 are extremely high: 69.3% in Togo, 68.3% in Senegal, 46.8% in Côte d'Ivoire and 44.1% in Mauritania (UNDP 2009, 2010; WHO 2010). Moreover, a significant part of the poorest population segments live in underprivileged settlements in the targeted secondary cities, and particularly in areas vulnerable to floods. For example, Kaédi (12 quartiers) and Ziguinchor (25 quartiers) are situated at low altitudes (<25 m above sea level), while Korhogo (20 quartiers) and Kara (27 quartiers) are situated at altitudes >200 m above sea level. Important economic activities that take place near water bodies in all four cities include urban agriculture, fishing and livestock production. Moreover, the water is used for domestic purposes such as washing clothing and dishes, and recreational activities such as swimming and bathing. Table 6.2 summarizes

Table 6.2 Socio-economic, demographic and vulnerability profiles of the four secondary cities

	Korhogo (Côte d'Ivoire)	Kara (Togo)	Ziguinchor (Senegal)	Kaédi (Mauritania)
Distance from capital (economic) city (km)	650	413	450	430
Altitude (m)	200	241	18	23
Estimated population	212,000	120,000	269,000	71,000
Demographic growth (%)	3	4.2	3	3
Rivers	None	Kara River	Casamance River	Senegal River
Other surface waters	Man-made dam, rain-fed, surface area: 10,000 m^3	None	Two small rivers (Boutoute et Djibélor)	Small rivers
Riverside neighborhoods exposed to floods	Sonzoribougou, Cocody	Tchinchinda, Kara-Sud	Santhiaba, Belfort, Goumel	Tantadje-Toulde, Gourel Sanghe, Kebbe, Pimpediel
Principal economic activities around rivers or dams	Urban agriculture, fishing, livestock production	Urban agriculture, fishing, livestock production	Urban agriculture, tourism	Urban agriculture, fishing, livestock production

Table 6.3 Adaptive capacity features in the four secondary cities, West Africa

	Korhogo (Côte d'Ivoire)	Kara (Togo)	Ziguinchor (Senegal)	Kaédi (Mauritania)
Administrative status	Municipality	Municipality since 1987	Municipality since 1990	Region and department capital city, seven municipalities
Number of administrative settlements	20 Quarters + 12 villages	27 Quarters	25 Quarters	12 Quarters
Local governance head (elected or nominated)	Mayor, elected since 2000	Special Delegation since 2002	Mayor, elected in 2009	Mayor, elected in 2007
Remaining time of the mandate	Unknown	31 December 2010	5 years	Less than 1 year
Annual budget of the municipality	650 million FCFA	65 million FCA (2000); 95 million FCFA (2003); 110 million FCFA (2006)	Five billion FCFA in 2010	50 M FCFA
University	One unit of the University of Bouaké	University of Kara	University of Ziguinchor	No university

key socio-economic and demographic data for the four targeted cities. Regarding the particular risks associated with floods, the most vulnerable settlements in each city have been identified.

6.4.4 Adaptive Capacities

Table 6.3 gives a summary of some adaptive capacity features. The four secondary cities all have legal municipal status with elected mayors at the head of the local government. While the mayors are in place for over 5 years in Korhogo (since 2000) and Kara (since 2002), they have been elected more recently in Kaédi (since 2007) and Ziguinchor (since 2009). The cities technical services are all facing a deficit of means to ensure total sanitation and drainage for the entire city. The level of municipal annual budget varies considerably from one city to another. While Kara and Kaédi have annual budgets of FCFA 50–110 millions (approximately 90,000 €) the budgets are an order of magnitude higher in Korhogo (FCFA 650 millions, approximately one million euros) and even two orders of magnitude higher in Ziguinchor (FCFA five billion, approximately nine million euros). Interestingly, prior to our kick-off workshop, none of the cities' mayors or staff had been associated in the analysis of climate change risks for their respective cities.

At the national level, however, each country has elaborated national adaptation plans for climate change. Thus far, translation of national plans to the local level has been lacking. Our project recognized the opportunity to develop such local action plans, seeking active collaboration of key stakeholders. Importantly, there are new funding opportunities to develop and implement specific climate change projects in West African countries; this dynamic bodes well for mitigation and adaptation to climate change. However, we are not aware that any of the four target cities have yet benefited from such projects. In fact, this is an important underlying reason for the choice of our cities; during the selection process, we involved the UNFCC national focal points, using their assistance to rationally choose cities of interest.

The active involvement of key stakeholders at the beginning of a project (i.e., choice of target city) is an important feature to ascertain committed participation at local and national levels. This helps facilitate future capacity building efforts and implementation. Universities have recently been established in Kara and Ziguinchor, and Korhogo has a special research unit as part of the University of Bouaké. Thus far, Kaédi has no university or relevant links to universities and research centres. Strengthening collaborative links with senior staff from local universities and research institutions was a goal right from the beginning of our project. Finally, community-based associations and NGOs have been mapped and those pursuing climate change-related activities will be tapped as they play an important role for change and in assisting local authorities and the most vulnerable communities to cope with flooding events.

6.5 Lessons Learned and Challenges

- Important gaps have been identified in the data collected on local levels thus far, particularly with regard to climate data, local health statistics, water resources development and management, and the availability of digitized maps. There are concerns about the accuracy of the assembled data, which call for additional efforts in triangulation techniques.
- One of the goals of our project is to support municipal planning in the elaboration of local adaptation plans to climate change. This challenge cannot be addressed upfront by our research project alone, but we feel that it is the only way forward. Hence, efforts were made to pursue this goal and build strong partnerships with the national climate change authorities and the local governance actors from the start of the project.
- Transdisciplinarity has yet to be incorporated in the academic research landscape of West Africa, even at well established universities. Hence, there is an urgent need to strengthen local human resources and link them with existing international networks. Long-term research partnerships, such as those in place between the Centre Suisse de Recherches Scientifiques en Côte d'Ivoire and the Swiss Tropical and Public Health Institute in Basel, Switzerland, based on the principles and experiences of north-south research partnerships (KFPE 1998, 2010) may serve as a role model.

- The concept of gender is often misunderstood and often attributed to sexual, biological or social differentials. Gender is usually not sufficiently taken into account by research teams. The teams need to be strengthened in knowing the gender analysis tools and how to take more explicitly gender dimensions in diverse levels of the project: gender balance in project team, gender integration in research questions and data collection tools, elaboration of gender-sensitive reports, implementation of gender-sensitive activities and interventions, partnerships with NGOs and policy makers that emphasize gender aspects.
- While the researchers may need time to collect sufficient data (both in terms of quantity and quality) in order to obtain robust results, the other actors are rather keen to have concrete actions as soon as possible. Within tight budget constraints for most research projects, there is considerable concern to keep the enthusiasm of the community and civil society throughout the process.

6.6 Conclusions and Outlook

The identification and preliminary analysis of climate data time-series in four selected secondary cities in West Africa confirms that rainfall patterns have changed and temperatures have increased over the past decades. Different stakeholders reported a higher frequency of flooding events. At the national level, floods and droughts are the most emphasized extreme climate events in the four countries where the project is being implemented. The targeted secondary cities are located near important river networks or other water bodies, and have many settlements prone to flooding. The resilience to flooding events seems higher in Kara than in the other cities. Nevertheless, in all four selected cities, there is a need for participatory action targeting the most vulnerable communities and environments. Here, capacity building must focus on the community itself and on local governance actors.

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Chapter 7
Climate Change and Adaptive Capacity of Women to Water Stress in Urban Centers of Nigeria: Emerging Concerns and Reactions

Isaac B. Oluwatayo

Abstract This paper examines the adaptive capacity of women in urban Nigeria to water stress resulting from climate change. Data were collected during both the rainy and dry seasons. A multi-stage random sampling technique was used in selecting 320 respondents from six city centres. Data analysis revealed that about 69% of these women rely on wells as a main source of water for domestic activities – drinking, washing, bathing and watering. Further analysis showed that about three-quarter rely on well water for drinking. However, on an adaptive measure, we found a sizeable number of women who resort to trekking in order to obtain water for domestic use, especially during the dry season. It was also revealed that rain water was occasionally stored in kegs and jerrycans for use during the dry season. Results using the Tobit model showed age, household size, educational status and income as determinants of the different water sources harnessed. While the coefficients of age, educational status and income were positive, those of gender, household size and primary occupation were negative. It is therefore suggested that more efforts are geared toward the education of women in order to enhance their income earning potential. Improvements of infrastructural facilities will help reduce the impacts of climate change, and proper sewage disposal and environmental sanitation will help keep urban streams in good condition.

Keywords Adaptive capacity • Climate change • Nigeria • Water stress • Women

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7.1 Introduction

Water is essential for food production, household domestic needs, industry, tourism, cultural practices, and sustaining the earth's ecosystems (Rosegrant and Cline 2002). However, this essential resource is under threat from climate change and is becoming one of the greatest challenges facing developing countries across the globe. Climate change aggravates the problems of food insecurity, poverty, HIV/AIDS and deteriorating infrastructure, which have plagued these countries for decades. Most of these countries already face unpredictable rainfall, which climate change is likely to worsen.

Climate change is likely to seriously affect urban centres and water utilities in Africa. As Moglia et al. (2008) suggest, the accelerating pace of urbanisation will make meeting urban water requirements a great challenge. Despite the commitments of the Millennium Development Goals to create universal access to safe water, efforts to provide urban water services often fail. A recent United Nations report (UNDP 2006) indicates that there has been surprisingly little progress in providing water and sanitation services to the world's poor. Access to safe drinking water and sanitation is critical for human health, particularly for children in developing countries (Bos and Bergkamp 2001).

Urban centres contain a large proportion of those most at risk from the effects of climate change. Many urban dwellers (especially women) face life-threatening risks from storms, flooding and landslides, all of which are increasingly affected by climate change. Their vulnerabilities are further complicated by their race, class, ethnicity and age. When natural disasters or dramatic environmental shifts take place, women and men are affected differently because of their different social roles, responsibilities and access to support within the community. Women are the most affected by water stress since more than half of the 1.2 billion people who do not have access to water worldwide are women and girls. Men, especially in rural areas, do not assist in collecting or carrying water. Their relationship to water has more to do with its storage and its use in agricultural work. This gender-determined inequality has implications on the daily lives of women from a rights-based perspective; carrying water not only causes women physical harm but it also takes them away from their involvement in education, income generation, politics and recreation (Oxfam 2005).

The improvement of water sanitation and water provision sits at the heart of development. Both vastly reduce disease and allow children, especially girls, to attend school. Women may also be relieved from the wretched daily burden of fetching water (IDC 2007). Relieving women and girls of their water-fetching burden would help promote gender equality and boost school enrolment. It is important to reiterate the many benefits that come with improved water and sanitation; namely, a reduction in disease and time saved. Both can translate into higher productivity and school attendance, especially for girls.

So far, little attention has been paid to adaptation in urban areas in Nigeria. Nigeria is witnessing rapid urbanization at a rate of 3.7% with about 50% of the population living in urban centres without commensurate investment in infrastructure. These conditions have led to huge urban populations without access to the most basic services (WaterAid 2007). The Nigerian National Water Resources Master Plan revealed that the country is endowed with 268 billion cubic metres of surface water and 52 billion cubic metres of ground water (Coker and Sridhar 2002). Although water may appear to be plentiful, many locations lack sources of potable water, especially major cities. Historically, surface water has been the major source of urban water supply. The infrastructure laid in the early 1960s, however, has since collapsed. Perennial water shortages have resulted in many communities resorting to alternative water supplies such as rain, springs, ponds and seasonal streams to augment their water needs.

In 2004, only 48% of Nigerians were estimated to have benefited from improved water sources (WHO/UNICEF 2006), leaving around 52% of the population without access to safe water. Between 1990 and 2004, access to safe water supply actually dropped by 1%. Clearly, Nigeria is not on track towards meeting the Millennium Development Goal target for water. According to a UNEP (1999) report, Nigeria is one of 25 African countries facing water scarcity or stress by 2025. The projection shows that Nigeria will witness water stress of about 1,000–1,700 m^3 per person per day. It is obvious, then, that a critical examination of the effect of climate change on the adaptive capacity of women to water stress in urban Nigeria is relevant and important.

7.2 Methodology

7.2.1 Study Area

Nigeria is considered to be blessed with abundant water resources. However, there are significant temporal and spatial variations in water availability across the country; for instance, the northeastern corner has low precipitation of around 500 mm, while the southeast has precipitation of over 4,000 mm. The country is drained mainly by the River Niger, its main tributary, the River Benue, and the various other rivers that discharge into the Lake Chad basin. Nigeria is located in the tropics with a climate varying from semi-arid in the North to humid in the South. The annual rainfall varies from over 4,000 mm in the Southeast to below 250 mm in the extreme Northeast and is subject to significant temporal variation.

7.2.2 Data Sources and Sampling Method

Primary data were collected through a questionnaire administered to 320 randomly selected women from six city centres (one from each of the six geopolitical zones) of the country – Ibadan in Oyo State from the Southwest, Enugu in Enugu State from the Southeast, Portharcourt in Rivers State from the South-south, Zuru in Kebbi State from the Northwest, Gombe in Gombe State from the Northeast and Minna in Niger State from the North-central. The states and the respective towns was selected randomly in order to make the data representative.

7.2.3 *Analytical Tools*

Descriptive statistics and the Tobit model were employed in data analysis. While the descriptive statistics was used to summarize and describe respondents' socio-economic characteristics, the Tobit model was employed to examine the determinants of the different adaptive measures used by the respondents. The Tobit model estimated takes the following form:

$$Y_i = f\left(X_1^* X_{10}, E_i\right)$$

where Y_i = index of adaptive measure = dependent variable

The explanatory variables (X_1–X_{10}) used were:

X_1 = Age (years)
X_2 = Marital status (married = 1, unmarried = 0)
X_3 = Household size
X_4 = Educational status (years)
X_5 = Primary occupation (farm = 1, off-farm = 0)
X_6 = Monthly income (Naira)
X_7 = Access to credit (yes =1, no = 0)
X_8 = Membership of association (yes = 1, no = 0)
X_9 = Distance to nearest water source (km)
X_{10} = Ratio of female member (number of female(s)/household size)
E_i = Error term

7.3 Results and Discussion

7.3.1 *Socioeconomic Characteristics of Respondents*

Households' socioeconomic characteristics were analyzed; the results are presented in Table 7.1. The distribution of respondents by age revealed that the majority were at an active working age, with a mean of 46 ± 1.5 years. About 57% of the respondents were married; the remaining (43%) were either single, divorced or widowed. The distribution of households by size revealed that respondents had fairly large families with an average of eight members. This explains why urban poverty in Nigeria is on the rise; as household size increases, per-capita income declines resulting in reduced well-being. Educational distribution of respondents indicated

Table 7.1 Distribution of respondents by socioeconomic characteristics

	Frequency	Percentage (%)
Age of respondents		
≤30	35	10.9
31–40	54	17.0
41–50	138	43.1
51–60	67	20.9
≥61	26	8.1
Total	320	100.0
Marital status of respondents		
Single	73	22.8
Married	181	56.6
Divorced	37	11.6
Widowed	29	9.0
Total	320	100.0
Household size of respondents		
1–3	48	15.0
4–6	80	25.0
7–9	125	39.1
10–12	41	12.8
≥13	26	8.1
Total	320	100.0
Educational status of respondents		
No formal education	150	46.9
Primary education	61	19.1
Secondary education	39	12.1
Tertiary education	70	21.9
Total	320	100.0
Primary occupation of respondents		
Farming	102	31.9
Trading	57	17.8
Civil service (government)	48	15.0
Artisans	64	20.0
Private salaried jobs	30	9.4
Others	19	5.9
Total	320	100.0
Income level of respondents		
≤10,000	122	38.1
10,001–20,000	85	26.6
20,001–30,000	43	13.4
30,001–40,000	34	10.6
≥40,0001	36	11.3
Total	320	100.0

that only about one-fifth had tertiary education. However, almost half (47%) of the respondents had no formal education, with only about one-third (31%) with either primary or secondary education. The distribution generally revealed low levels of education among urban residents in Nigeria. Respondents' occupational distribution generally explained the relative importance of farming as the main source of livelihood for the majority (one-third) of respondents. This was closely followed by artisans (20%). This is not uncommon in most city centres as artisanal activities are extremely lucrative. Respondents' distribution by income level showed that about 38% were low income earners, with a monthly income below 10,000 naira. This was closely followed by those earning between 10,000 and 20,000 naira. In all, only about 10% of the respondents earned income that could be considered adequate – an indication of the low level of well-being and rising poverty levels among urban residents in Nigeria.

7.3.2 Housing Unit of Respondents

The distribution of the types of housing units occupied by respondents (Table 7.2) show that about 44% live in rooms with a parlour. This is followed by those occupying single rooms. The distribution clearly revealed the poor living conditions of urban residents in Nigeria. With an average household size of eight, this implies that about four people occupy a room at a time. In total, only about 28% of respondents lived in flats, duplexes or other similar types of housing units.

7.3.3 Sources of Water Harnessed by Respondents

As Table 7.3 illustrates, wells remain the main source of water for most (69%) urban dwellers. Only about one-tenth obtained their water though piped sources – less than 15% of the houses studied have connections to piped water sources. Other water sources include boreholes (7%), rain water (6%), packaged, sachet or bottled water supplied from vendors (4%), streams and ponds (2%) and other sources (1%).

7.3.4 Types of Water Use

The distribution in Table 7.4 shows that drinking alone constituted the major activity in which water was consumed. Because wells remain the main source of water for urban residents, about three-quarters rely on them for drinking as depicted in row

Table 7.2 Distribution of respondents by housing unit occupied

Housing unit	Frequency	Percentage (%)
Single room	89	27.8
R/Parlour	142	44.3
Flat	63	19.7
Duplex	22	6.9
Others	4	1.3
Total	320	100.0

Table 7.3 Distribution of respondents by water sources harnessed

Water source	Frequency	Percentage (%)
Pipe-borne water	35	10.9
Borehole	23	7.2
Well water	219	68.5
Rainwater	18	5.6
Vendor	13	4.1
Streams	7	2.2
Pond	3	1.0
Others	2	0.6
Total	320	100.0

Table 7.4 Distribution of respondents by activities through which water is used

Activity	Piped water	Borehole	Well water	Rainwater	Vendors	Streams	Pond	Total (%)
Drinking	10.9	6.1	75.2	5.6	2.2	–	–	100
Washing	4.1	3.3	73.1	7.4	3.1	5.7	3.5	100
Cooking	7.6	8.2	68.0	11.3	4.9	–	–	100
Bathing	10.0	7.2	73.7	4.3	2.1	1.3	1.4	100
Watering	3.9	6.3	71.4	4.8	2.0	5.9	6.7	100.0

1, column 4 of Table 7.4. In fact, well water was also the most used for all other activities since it is the most available and affordable water source. This was closely followed by piped water and borehole water, which is used by 11% and 6% of the respondents respectively.

7.3.5 *Adaptive Measures for Water Stress*

A number of adaptive measures are employed by Nigerian women in an attempt to mitigate the effects of climate change. As revealed in Table 7.5, 53% resorted to trekking several kilometres in search of water. This especially occurred during the dry seasons when the water table was low and water available in nearby wells, streams or ponds became inadequate. The high level of poverty in these cities further makes this measure an important means of circumventing the problem. About 20% of respondents relied on rainwater stored in kegs and jerry cans collected during the rainy season for use n the dry season. Other adaptive measures included buying sachet or bottled water from vendors and processing and boiling waste water from domestic chores.

7.3.6 *Determinants of Adaptive Measures to Water Stress*

A number of factors were found to influence the adaptive measure(s) adopted by the respondents. From the results shown in Table 7.6, age, household size, educational status, income and primary occupation were found to be important.

Table 7.5 Distribution of respondents by adaptive measures employed

Adaptive measure	Frequency	Percentage (%)
Trekking in search for water	169	52.8
Storage of water in kegs and cans	64	20.0
Buying from water vendors	42	13.1
Relying on sachet and bottled water	32	10.0
Processing/boiling of waste water	13	4.1
Total	320	100.0

Table 7.6 Result of Tobit regression on the determinants of water stress adaptive measures

Variable	Coefficient
Age (X_1)	2.8345**
	(1.0013)
Marital status (X_2)	0.0141
	(0.0201)
Household size (X_3)	−0.3799***
	(0.0721)
Educational status (X_4)	1.1508**
	(0.5827)
Primary occupation (X_5)	−0.2936*
	(0.0441)
Monthly income (X_6)	0.3372***
	(0.0642)
Access to credit (X_7)	0.0114
	(0.5901)
Membership of	2.9503
association (X_8)	(2.0017)
Distance to nearest water	−0.3166**
source (X_9)	(0.1105)
Ratio of female	−0.4012*
member (X_{10})	(0.1716)
Constant	3.0523
	(2.8500)

Figures in parenthesis are standard errors
*** Coefficients significant at 1%
**Coefficients significant at 5%
*Coefficient significant at 10%

The coefficients of age, educational status and income were positive, indicating that educational level and income play a significant role in determining what adaptive measures are employed. In other words, the higher the educational level and income of respondents, the higher the probability that they adopted better and cost-effective measures. This was true irrespective of the season, wet or dry.

While the coefficients of age and educational level of respondents were significant at 5% ($p < 0.05$), income was significant at 1% ($p < 0.01$). However, the coefficients of household size, primary occupation and distance to nearest water source were negative. This indicates that as household size increases, the lower the likelihood that respondents adopted better adaptive measures since increased household size reduces income per-capita. Respondents whose primary occupation was farming preferred trekking in search of usable/potable water to purchasing water with the small income earned from their farming activities.

7.4 Summary, Conclusion and Policy Recommendations

This study examined the adaptive measures adopted by urban women in Nigeria in their effort to obtain potable water. Analysis of respondents' socioeconomic characteristics revealed that average age was 46 years and average household size was 8. Around half of those surveyed had no formal education. Analysis of adaptive measures employed by respondents indicated that most trekked in search of potable water (due to their low income levels). Again, a sizeable number stored rainwater in kegs and jerry cans for use during the dry season. Meanwhile the result of the Tobit model showed that age, household size, educational status, income and the number of female member available in the household were very significant. While the coefficients of age, educational status and income were positive, those of household size and distance to nearest water source were negative.

Based on the study findings, it is clear that women in urban Nigeria go through considerable stress in order to access water for domestic chores. One of the factors limiting their access to water is poverty. Moreover, the household size of respondents was discovered to contribute to their level of wellbeing; larger sized households often had lower levels of wellbeing due to their low per-capita income. Dilapidated infrastructure was also found to contribute to poor water and sanitary conditions in city centres. Associated with this were poor housing conditions resulting from overcrowding and the overuse of existing social infrastructure. Based on the foregoing, the following is recommended:

1. More effort should be made to better educate women and girls since education provides a means to improve the earning potential of residents and their capacity to make wise decisions.
2. Infrastructural facilities in city centres should be improved to help reduce the impact of climate change on urban dwellers.
3. Creating awareness of environmental sanitation and management through proper sewage disposal will help keep urban streams and ponds in good condition and improve existing water sources in the cities.

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Chapter 8
Urban Climate Strategies Against Future Heat Stress Conditions

Lutz Katzschner

Abstract Recent climate change studies predict an increase of temperature in Central Europe. These conditions – intensified by the urban heat island effect – are expected to have consequences on the quality of human life in urban areas in the future. Urban design must respond to these changes in the urban climate and, by following the precautionary principle, must ensure that in the future thermal stress for people outdoors and indoors is reduced to a tolerable degree. The application-related basics needed for this have been developed by an interdisciplinary team from the fields of urban climatology, urban development and geoinformatics. This project aims to develop strategies and concepts for urban planning to mitigate the impacts of climate extremes on the well-being and health of city residents. In experimental analyses, surveys and simulations on the thermal comfort of people, and draft modules suitable for practical application in urban planning adapted to the climate, have been developed and summarised in a manual. Urban quarters in Germany, Brazil and Hong Kong have been selected as examinations sites.

Keywords Thermal comfort • Thermal sensation • Urban climate

8.1 Urban Climate and Thermal Comfort

According to recent studies on climate change, an increase of temperature in Central Europe is predicted. This change is intensified by the urban heat island effect, which is expected to affect the quality of human life in urban quarters with greater intensity in the future. The issue of human comfort in relation to existing urban structures is coming to the fore (Katzschner et al. 2007), along with a growing recognition of the

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need for planning strategies that ensure outdoor human thermal comfort during extreme heat waves.

Recently, there has been strong public interest in the quality of open urban spaces. As part of the growing discussion over the concept of new urbanity, the issue of revitalizing cities has become more and more important. Therefore, in order to increase the use of outdoor space and follow the idea of revitalising cities, environmental conditions and thermal comfort – both of which affect people using these spaces – have to be considered and improved.

To understand thermal comfort and its effects on human beings, air temperature is not an adequate indicator. Instead, thermal indices should be used. In this study, the physiological equivalent temperature (PET) is used to calibrate urban climate classification in different climate areas and the urban climatic maps (Ng 2010). Figure 8.1 show an urban climate analysis of heat load in Frankfurt and Hong Kong. To evaluate the urban heat island situation, the frequency of hot days above 25°C were counted. The classifications in Fig. 8.1 of the urban climatic maps are based on the thermal heat load expressed as the index PET, which was evaluated through the results of interviews concerning the thermal sensation of people. To account for the increase of hot days in the future, scenarios of global warming can be used.

Regarding the increase of hot days and their spatial distribution during the period of 1950–2005 in the city of Frankfurt (see Fig. 8.2). In Germany, cities like Frankfurt show an increase in the number of hot days – though this trend is not distributed equally throughout the city. Variations in density across the city affect heat load and therefore have different air temperature increases. In Frankfurt, people have been observed to complain after experiencing 46 days of temperatures above 25°C, while in Hong Kong, for instance, this is accepted as a normal occurrence, where air temperatures greater than 25°C occur an average of 255 days of the year. This indicates that thermal comfort should be considered according to regional climates.

As studies of urban heat islands (UHI) show, differences in temperature can vary by more than 5°C during night hours. This situation is aggravated by global warming (Katzschner et al. 2009). An increase in incoming radiation can lead to greater heat storage, contributing to intensified UHI. To demonstrate this in terms of thermal comfort, the index PET (Höppe 1999) gives a thermal evaluation. Moreover, PET provides a better understanding of the influence of radiation and wind speed on thermal comfort and heat stress, which enables planners to respect these factors in their urban design.

8.2 Methodology

To develop strategies in urban design, urban climate conditions need to be classified as in Fig. 8.1. At the same time, however, an evaluation should be carried out in order to judge future trends in heat load. Therefore the urban climate

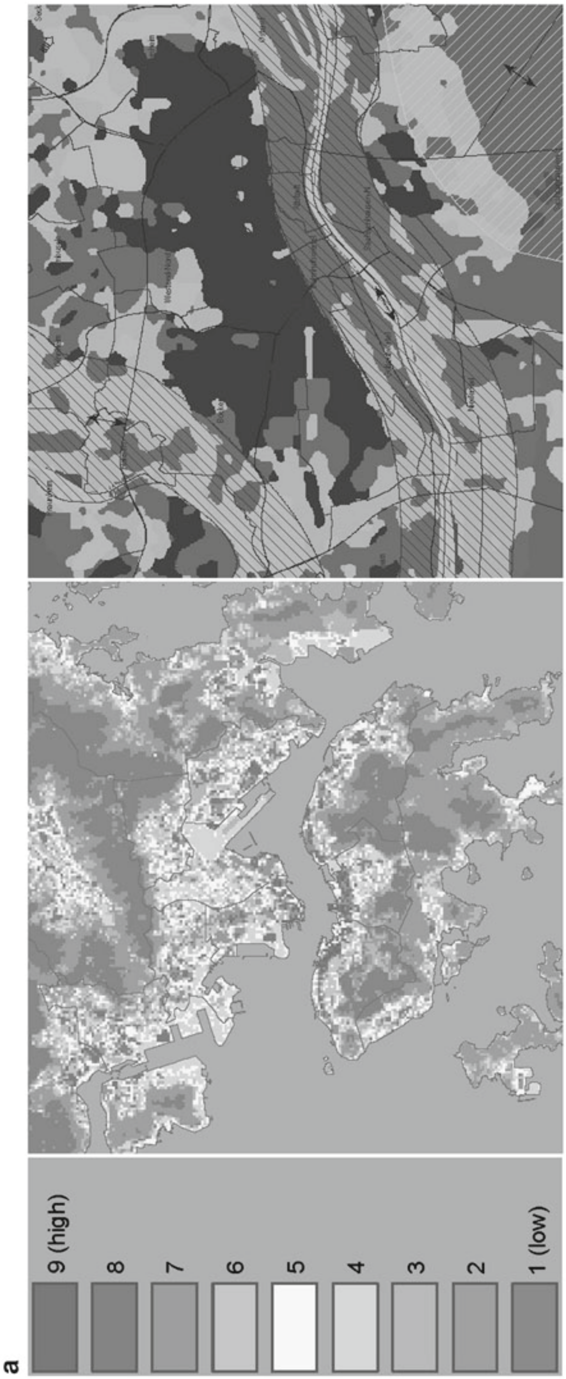
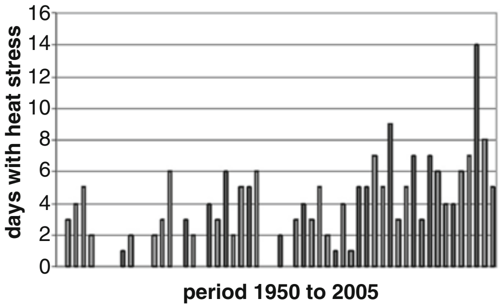


Fig. 8.1 (**a**, **b**) Urban climate analysis of heat-load in Frankfurt and Hong-Kong

b

classification	name	description	PET	evaluation
1	**fresh air productions or air path**	minor roughness and minor heat capacity mainly agricultural areas	22 C	very important for climate, high protection
2	**fresh air production on slopes**	forests and trees	24 C	important for circulation to keep and maintain
3	**mixed climates with local circulation pattern**	parks, gardens	26 C	important linkage areas, foresee the orientation and density
4	**heat island potentials**	urban areas with roughness but vegetation links	28 C	thermal air pollution problens, mitigation through ventilation and vegetation, heat stress increasing
5	**heat island**	dense built up areas with considerable roughness and heat load	30 C	heavy thermal load should be mitigated, heat stress problems, extremely increasing
6	**heat island max**	extremly dense areas nor vegetation (city centre)	32 C	heavy thermal load should be mitigated, heat stress problems, extremely increasing

Fig. 8.1 (continued)



Increase of hot days in urban areas:	
Calculation by the DWD (German Weatherservice) on base of urban climate map in the city of Frankfurt/Germany T_{air}>25°C	
Annual heat stress today in Frankfurt	46 days
Scenario 2050	
increase at airport	3 days
increase city parks	4 days
Increase residential areas	6 days
Increase in dense structures	11 days

Fig. 8.2 Increasing number of hot days (t_a > 25°C) in the city of Frankfurt (1950–2005) and increase taken a scenario depending on city structures

classifications were calibrated by PET values. Calculations of spatial distribution on urban heat load based on radiation balance and the dynamic pattern based on roughness length were linked with interviews to gather information on people's perceptions. Carrying out on-site interviews and parallel meteorological measurements at the exact same point ensures a direct comparison of subjective and objective data.

This was achieved through mobile meteorological measurements together with interviews with a temporary reference station and two mobile recording systems. The meteorological parameters measured were air temperature, wind and humidity, as well as horizontal and vertical radiation. Using this methodology, every person's subjective perception can be related to objective data collected by the mobile station. The mobile station measures meteorological data as mean values of 3-min intervals, which is then transferred into the thermal index PET.

The index PET was chosen for various different reasons. First, it is conveniently adapted to outdoor settings. Second, it is widely used at an international level, which allows for comparison and replicability. And third, its required parameters are easily calculated. Additionally, the use of Celsius is a widely accepted unit as an indicator of thermal stress and thermal comfort; this makes the results easy to communicate and comprehensible for potential future users.

PET is a steady-state model involving all heat exchange processes between the human body and its environment. PET evaluates the thermal conditions in a physiologically significant manner. It is defined by Höppe (1999) as 'the air temperature at which the human energy budget for the assumed indoor conditions is balanced by the same skin temperature and sweat rate as under the actual complex outdoor conditions to be assessed.' The meteorological input parameters include mean radiant temperature (Tmrt), air temperature (Ta), wind speed (v) and vapor pressure (RH). PET enables various users to compare the integral effects of complex thermal conditions outdoors with their own experience indoors. PET also considers the heat transfer resistance of clothing and internal heat production.

8.3 Evaluation of Thermal Comfort Conditions

To study thermal comfort, the benchmarks of indices have to be considered depending on the regional climate and the urban situation. Therefore, it is not possible to only refer to one index value worldwide. A calibration of PET, using ordinal regression analysis, applying data from Hong Kong, Brazil and Germany, shows differences in perception concerning heat stress. Mobile measurements and interviews were conducted in two different climates during different seasons in Germany and Hong Kong. The data were used to calibrate the PET (Table 8.1).

To calibrate the PET value, ordinal regression analysis was used following the assumption that the measurement scale – very hot, hot, warm, comfortable, slightly cool and cool – have different intervals. This means the cut off point from very hot to hot is defined differently than the interval between hot and warm (Fig. 8.3). Due to this non linear relation, then, it would not be accurate to use linear regression analysis.

While the comfort zones vary between the different climates by 6°C PET, it is obvious that in the warmer categories differences decline (Table 8.1). Differences are also due to the fact that in the study of Germany, four categories measuring heat stress were used, while in the subtropical climate, only three were used. So the subjective perception of hot – i.e., high heat stress – in both climates start around a value of 35°C (PET).

Since we are interested in the conditions of heat stress, the most important value is the benchmark between comfortable and warm, as this represents the point at

Table 8.1 Calibration of PET (°C) in Germany (n = 776), Hong Kong (n = 1,958) and Brazil (n = 706) based on empirical data

PET (°C) (Germany)	PET (°C) (Brazil)	PET (°C) (Hong Kong)	Subjective perception	Level of stress
More than 42	More than 43	More than 45	Very hot	Extreme heat stress
35–41	35–42	35–45	Hot	Strong heat stress
29–34	31–35	30–35	Warm	Moderate heat stress
18–28	26–30	12–30	Comfortable	No thermal stress
13–17	–	9–12	Slightly cool	Weak cold stress
Less than 13	Less than 13	Less than 8	Cool	Cold stress

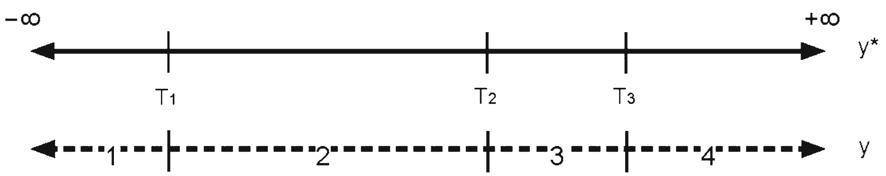


Fig. 8.3 Visualization of the differences concerning the cut points in the answering categories (Source: Nonnenmacher 2005)

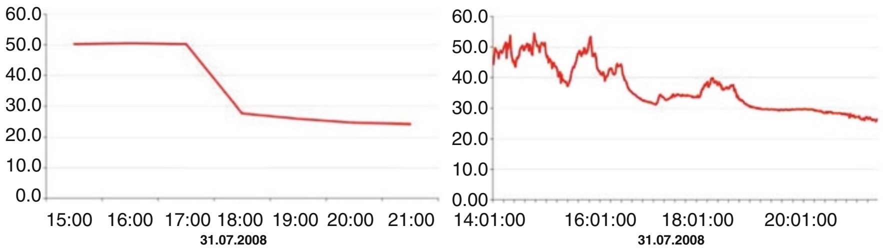


Fig. 8.4 Thermal comfort index (PET) from modelling and measurements

which heat stress begins. Therefore, 28°C (PET) in Germany, 30°C (PET) in Hong Kong and 31°C (PET) in Brazil can be determined. Values were very difficult to compare within the cool classification, since in Hong Kong nearly no cool sensation from interviews could be found. The main focus, then, was on the comfortable and hot zones where health risks are expected after a certain point.

On July 31, 2008, measurements were taken on the Opernplatz in Kassel. Figure 8.4 shows the daily course of thermal comfort using the meteorological model ENVI-met compared to the spot measurements. The graphs show a warm day with significant cooling in the late afternoon. These measurements match the result of thermal comfort. The graphs show the daily variation of the thermal index (PET) on the left and the conducted measurements on the right. Wind speed, an important factor in thermal comfort, is partly responsible for the observed variation in the data. In principle, the daily variation from the ENVI-met model compared with the on site measurements was sufficient accuracy for a thermal comfort evaluation.

The mean thermal sensations of people throughout the day showed comfortable to neutral conditions. However, behaviour and sensation were observed to change during the course of the day; as Fig. 8.5 illustrate, the cooling period during the evening seemed to affect thermal sensation, with a decrease in discomfort during these hours. This is due to reduced radiation and wind on this particular day. The situation during cloudy conditions is different. One can see that a decrease in PET does not automatically lead to a more neutral thermal sensation, but does decrease heat stress.

Further studies show that high variation in microclimates tends to be evaluated positively (Katzschner 2006). One central issue of the project is to evaluate whether certain urban structures affect heat stress more than others in terms of microclimate and subjective perception. Therefore, guidelines should consider the variations of microclimates inside urban structures (EU RUROS 2004). The factors which can be influenced by urban design include mean radiation temperature and wind speed. Higher wind speeds in particular seem to be negatively perceived by people living in moderate climates – though positively perceived in warmer climates.

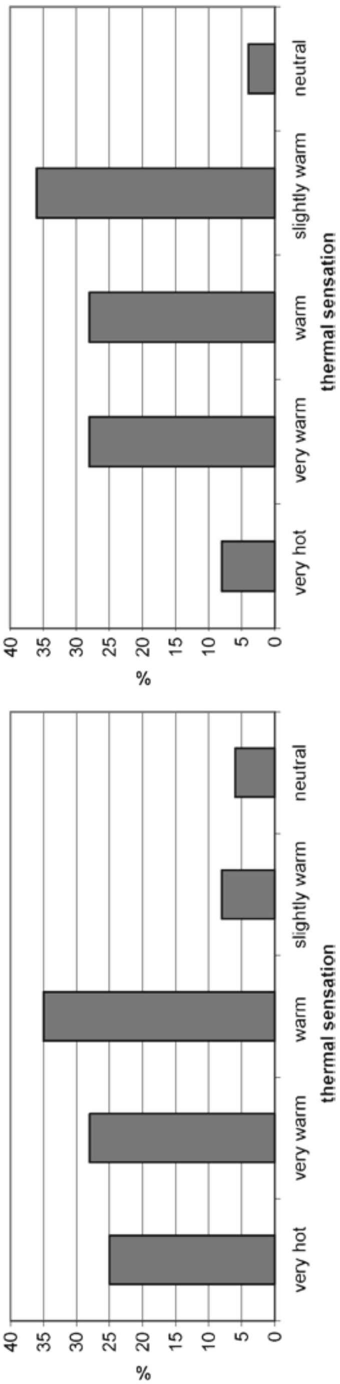


Fig. 8.5 Thermal comfort sensations from interviews before (*left*) and after (*right*) the cooling period at 4:30 p.m.

8.4 Urban Planning

For planning purposes, it is important to identify spatial patterns of heat stress in order to develop thermally comfortable areas. To accomplish this in Kassel, microclimatic maps of one urban area within the city were produced (Fig. 8.6). These were derived from small scale measurements and a calculation using ENVI-met. Heat stress can be defined as occurring at values above 34°C PET following the presented calibration (Table 8.1). The example of Opernplatz shows that people are very tolerant of heat stress as long as they have the choice between different microclimatic conditions. Nevertheless, the analysis shows that PET values of more than 30°C cause discomfort and heat stress. According to these findings, planners should create varied microclimates within their cities and encourage heat reduction through shading.

During the hottest period of summer in the city of Kassel people were observed to avoid locations that exhibited the highest temperatures. Shade, if available, and areas with wind seem to be comfortable in the range of 30–50°C PET. The spatial distribution of interviews conducted on Opernplatz in Kassel (Fig. 8.6) show this pattern of usage.

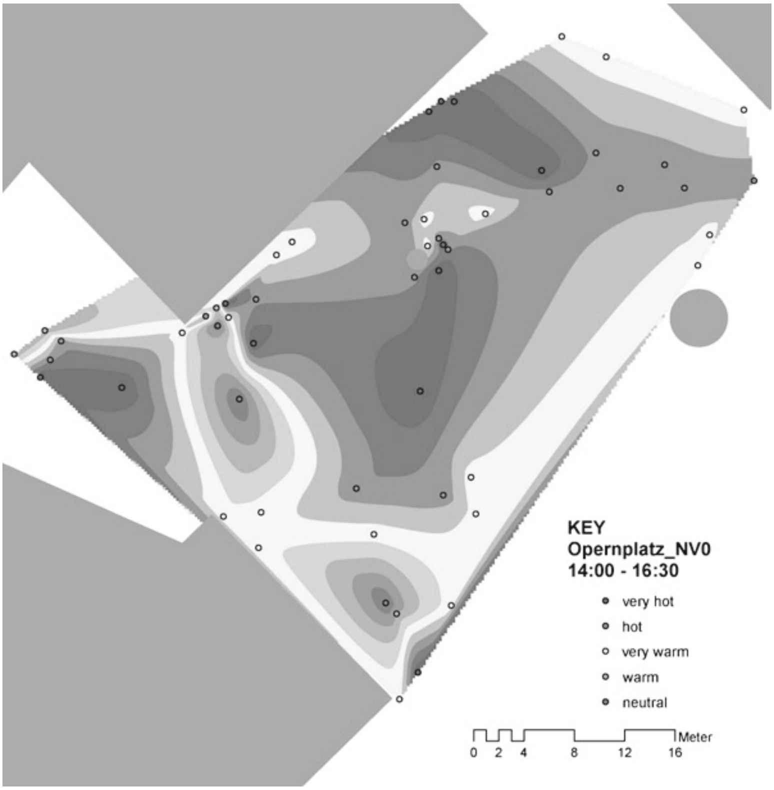


Fig. 8.6 Spatial distribution of thermal sensation from interviews in Kassel/Germany at 3 p.m.

Predictably, the hottest spots of the Opernplatz (which is exposed to the sun nearly all day) are avoided. As can be seen in Fig. 8.6, the Opernplatz is completely sealed and contains few trees that provide shade. To gain information from interviews that could be useful to planners, it was necessary to link the interviews with the distribution of PET values in this location to get the spatial distribution. To accomplish this, a simulation using ENVI-met was conducted and maps were generated.

The map simulated with ENVI-met revealed hot spots as well as recreational spots within Opernplatz. The subjective perception map aligned closely with heat sensitive areas. This, in combination with the calibration tables, is helpful advice for planners considering the redesign of urban open places, and is becoming even more important in light of global climate change and increased periods of heat stress.

8.5 Conclusion

Global climate change and urban climate cannot be dealt with separately. Urban heat islands and concomitant heat stress will increase. Therefore, urban planners will require more quantitative information to mitigate future stress conditions. As stated above, knowledge of microclimatic conditions need to be mapped so that measures can be taken to mitigate heat stress. For cities that aim to reduce their heat income during the day and retain their cooling capacity during the night, there are various options. The first can be achieved by using shade, reflective materials and thermally induced circulations. To achieve nightly cooling, adequate air mass flow is needed. While heat reduction can be achieved through open space planning – that is, by improving surface conditions, building orientation and building design – the issue of ventilation and local air mass exchange requires knowledge derived from urban climate analysis on a mesoscale. To introduce these aspects into the urban planning system, it is important to keep in mind that different scales require different approaches. Building design and open spaces can be integrated into neighbourhood and design planning, while ventilation has to be considered on the urban development planning layer.

Future city developments should also take into account the use of open space and how this is connected to thermal conditions. The simulations can help guide decisions for the improvement of thermal conditions through the use of materials and structural arrangements; for example, through the use of facades, shade and ventilation.

Thermal conditions should always be considered in terms of the specific use of a particular open space. The interviews on thermal sensations suggest that varied microclimates provide the best conditions for people. During hot summer days, shade and moderate temperature zones should be available within walking distance. Microclimatic analysis can be obtained from ENVI-met simulations and measurements so that bioclimatic designs of open space can be conducted.

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Chapter 9
Climate-Proof Urban Transport Planning: Opportunities and Challenges in Developing Cities

Urda Eichhorst, Daniel Bongardt, and Montserrat Miramontes

Abstract Transport plays an important role in all human activities, especially in urban areas where most economic and social activities involve the movement of persons or goods. Many transport decision-makers in developing countries are already confronted with extreme weather events, such as flooding, subsidence and storms, all of which are expected to increase with climate change. In the worst case, transportation systems may be unable to recover from such events, resulting in exponential damages. In order to deal with climate change, transport systems must be designed to cater for the mobility demand of all urban populations under changing climatic conditions and to minimise transport-related greenhouse gas emissions. In many cities, decision-makers are not prepared to address these needs at the planning and design stages of urban development. As many urban areas in developing countries are still undergoing rapid development, the time to build climate-proof urban systems is now. This paper gives an overview of the expected impacts of climate change on urban passenger transport as well as possible adaptation measures. It further discusses how to integrate climate proofing into urban transport planning and policy implementation, emphasising the importance of cross-departmental cooperation. Seven steps towards developing an adaptation strategy for urban transport and how they integrate into the main steps of transport planning are presented.

Keywords Adaptation • Climate change • Developing cities • Urban transport

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9.1 Introduction

Transport is linked to all aspects of urban life: leisure, education, business and industry. Nevertheless, little attention has been paid to the vulnerabilities of urban transport systems to climate change. Ensuring a resilient urban transport system is, however, necessary to avoid frequent disruptions of urban life and associated social and economic costs. As current weather impacts on transport are expected to become more frequent and more extreme in the future, adaptive measures must be taken. Studies on the overall impacts of climate change on transport have emerged in recent years in Europe and North America. This paper gives an overview of these findings and sets them in the context of adaptation of urban passenger transport[1] in developing cities. It further provides orientation on how to integrate climate proofing into urban transport planning and policy implementation. The paper is based on Eichhorst (2009), 'Adapting Urban Transport to Climate Change,' a module of GTZ's sourcebook for decision makers in developing cities (see www.sutp.org).

9.2 Developing Cities and Climate Change

Cities are both a major source of greenhouse gas emissions and subject to the impacts of climate change. With high population and infrastructure density, as well as concentrated economic and social activities, cities are particularly vulnerable. The expected impacts of climate change on cities include increased temperature and heat waves, more frequent droughts, sea-level rise, more extreme rainfall events and more intensive and frequent storms (Dawson 2007; IPCC 2007).

Many climate impacts are worsened in cities due to certain aspects inherent to urban development. For example, urban infrastructure hinders the natural drain of water, which increases the risk of flood events. Moreover, urban activities such as transport, air conditioning and industrial processes have direct impacts on the climate and air quality because of the emissions related to their energy use, including heat exhaust.

Urban areas in many developing countries are characterized by chaotic and discontinuous spatial patterns, as well as unorganized and fast development processes (Barros 2004). These characteristics often have negative impacts on mobility and transport in developing cities. Due to rapid urbanisation rates in developing countries, transport systems often operate at capacity, providing little buffer for unexpected impacts. Informal settlements further increase the vulnerability of developing cities. Significant numbers of urban populations live on flood plains or

[1]Although many impacts on freight transport are similar to passenger transport, in particular regarding transport infrastructure, freight transport is subject to different dynamics and requires a separate assessment, which is beyond the scope of this paper.

otherwise perilous areas with low quality or no transport infrastructure at all. At the same time, many developing cities are already heavily exposed to extreme weather impacts such as tropical storms, heavy flooding and heat waves, all of which are expected to get worse under climate change.

In certain parts of developing cities, where only rudimentary transport infrastructure exists, adaptation will actually require building resilient infrastructure in the first place. Developments that increase the vulnerability of cities by ignoring climate change implications, such as settlements in flood plains, must be avoided. As many urban areas in developing countries are still undergoing rapid development, the time to build climate-proof urban systems is now.

9.3 Likely Impacts on Urban Transport and Potential Adaptation Measures

Due to the interconnectivity of urban transport infrastructure, impacts on a single element can often lead to a domino effect, causing disruptions larger than the initial climate impact itself. For instance, the interruption of urban transport due to flooding can lead to indirect economic losses as people miss work and goods are left undistributed. Cascading effects can also lead to human suffering or death; critical services like hospitals may become inaccessible due to flooded or disrupted access routes. Adverse effects can be particularly large when poorly connected areas are completely cut-off, central transportation hubs are affected, or the transport system is working close to its capacity. This has implications for enhanced disaster risk strategies and evacuation plans, which rely heavily on reliable transport systems and are needed in addition to adaptation measures.

The climatic impacts on transport can be classified into three categories: impacts on transport infrastructure, impacts on vehicles and operations, and impacts on mobility behaviour.

9.3.1 Transport Infrastructure

Transport infrastructure in cities generally includes roads, rails and waterways. While the first two are similar in many respects, waterways need to be analyzed separately. In this paper, only the first two types of transport infrastructure are presented in detail. For information on waterways please refer to Eichhorst (2009).

Table 9.1 gives a detailed overview of the relevant climate impacts on road and rail infrastructure, as well as possible adaptation measures. Road infrastructure in this paper is used as a collective term for roads, bicycle lanes and walkways.

In summary, impacts on road and rail infrastructure and the resulting restrictions in their use can cause congestion, accidents and disruption of mobility services.

Table 9.1 Summary of key climate change impacts and adaptation responses for road and rail infrastructure (Cochran 2009; Eddowes et al. 2003; ODPM 2004; Savonis et al. 2008; Wooler 2004; Woolston undated)

Relevant climate impacts	Impacts on road and rail infrastructure	Possible adaptation measures
Increased temperature and more heat waves	Deformations of roads, slowing down or disrupting transport; melting of asphalt/dark surfaces	Planting roadside vegetation to decrease the exposure of roads to heat
	Increased asphalt rutting due to material constraints under severe exposure to heat	Reduce overall exposure and provide cooling through green and blue infrastructure, such as parks and lakes, but also road-side trees or other shading
		Proper design/construction, overlay with more rut-resistant asphalt or more use of concrete
		More maintenance, milling out ruts
	Thermal expansion on bridge expansion joints and paved surfaces	New design standards may be needed to withstand higher temperatures
	Bridge structural material degradation	Increased maintenance
	Buckling of rails and rail track movement because of thermal expansion leads to slowing or disruption of transport	Adapted maintenance procedures, such as rail stressing in the USA
		New design standards may be needed for rails to withstand higher temperatures
		Management procedures to impose differentiated speed limits
		Improve systems to warn and update dispatch centres, crews, and stations. Inspect and repair tracks, track sensors, and signals.
		Distribute advisories, warnings, and updates regarding the weather situation and track conditions.
	Increased temperatures in underground networks (and trains)	Better (and flexible) cooling systems or air conditioning for underground networks, vehicles (trains) and metro stations
		Temperature monitoring for underground infrastructures
		Hot weather contingency plans

(continued)

Table 9.1 (continued)

Relevant climate impacts	Impacts on road and rail infrastructure	Possible adaptation measures
		Design standard for power supply to meet anticipated demand within the life of the system (especially higher demands due to increased air conditioning needs in trains)
More frequent droughts (and less soil moisture)	Dry soils in combination with more intense rains will lead to more landslides and subsidence	Assess the likeliness of impacts on infrastructure (risk mapping)
	Road foundation degradation due to increased variation in wet/dry spells and a decrease in available moisture	Avoid new developments in high-risk areas
	Dust and sand on roadways can be a safety hazard from several perspectives including reduced friction in braking, as well as less sighting of roadway markings	Monitoring of soil conditions of existing roads
		Increased cleaning and maintenance of roadways
		Monitoring of high risk tracks and regular maintenance
		Avoid new rail lines in high-risk areas
Sea level rise and coastal erosion	Risk of inundation of infrastructure and flooding of underground/subterranean tunnels in coastal cities	Create vulnerability maps to identify areas most at risk
	Degradation of the roadway surface and base layers from salt penetration	Restrict developments in high-risk areas, e.g. along the shoreline; zoning
		Integrate transport planning with coastal zone management
		Enhance protective measures, such as sea walls, protection of coastal wetlands (as buffers), pumping of underground systems
		Managed retreat, possibly including abandoning of certain transport infrastructure in the mid to long term
		Build more redundancy into system
		Design and material changes towards more corrosion-resilient materials
		Improved drainage, pumping of underpasses and elevating roads

(continued)

Table 9.1 (continued)

Relevant climate impacts	Impacts on road and rail infrastructure	Possible adaptation measures
More extreme rainfall events and flooding	Flooding can affect all transport modes. The risks are greater in flood plains, low-lying coastal areas and where urban drains are overloaded or non-existent	Improve drainage infrastructure to be able to deal with more intense rainfall events, increasing capacity of drainage infrastructure to deal with increased run-off; include tunnels under large roads to facilitate speedy drainage
	Flooding of infrastructure and subterranean tunnels, especially where drainage is inadequate	Audit drains regularly
	Infrastructure damages and decrease of structural integrity due to erosion, landslides and increasing soil moistures levels.	Enhanced pumping
		Create flood maps to identify most vulnerable areas, where infrastructure needs to be protected/improved/avoided in the future and assess alternative routes (this is vital for evacuation plans)
		Make flood-risk assessments a requirement for all new developments
		Restrict developments in high-risk areas
		Improve flood plain management/ coastal management and protective infrastructure
		Early warning systems and evacuation planning for intense rainfall events and floods
		Install signs high-above the ground that can alert pedestrians and motorists of unsafe zones, such as low-lying areas
	Higher rivers or canals can lead to undermining and washing off of bridges	Ensure that bridges and related infrastructure is resilient to expected levels of flooding
	Dirt roads and other roads with limited foundations and poor or no drainage are at risk of being washed away or scoured	Enhance foundations
		Build all-weather roads
		Improve green spaces and flood protection

(continued)

Table 9.1 (continued)

Relevant climate impacts	Impacts on road and rail infrastructure	Possible adaptation measures
	Subgrade material underneath roads or pavements may be degraded more rapidly, loosing strength and bearing capacity	Enhance condition monitoring of subgrade material especially after heavy rains, flooding
		Regular maintenance
More extreme rainfall events and flooding	Increased weathering of infrastructures	Use more durable material, such as more corrosion resistant material
	Underground systems/tunnels may be flooded, especially where drainage is inadequate	Passenger evacuation plans for underground systems
		Enhanced pumping
		Create vulnerability maps to identify areas of high flood risk
		Restrict developments in high-risk areas
	Stability of earthworks can be affected by intense precipitation due to build up of pore water pressures in the soil, especially after periods of hot and dry weather	Enhance condition monitoring of earthworks, bridges, etc. especially after heavy rains, flooding (or storms)
	Subgrade material underneath rails may be degraded more rapidly, loosing strength and bearing capacity	Improved maintenance
	Failure of track circuits with subsequent disruptions due to inability to detect the presence or absence of trains on rails and inability to send related signals	Adapted technology standards
More intensive and frequent storms	Damage to stations/infrastructure fabric, bridges, flyovers, electrified tracks with overhead cables, train platforms street lighting, signs and service stations	Assess if currently used design standards can withstand more frequent and intense storms
	Risk of inundation by the sea during high winds, especially in combination with high tides and sea level rise	Adapt design standards for new bridges, flyovers, buildings, etc. to expected increases of wind speeds and heavy rains
	Obstruction of roads due to fallen trees, buildings or vehicles because of strong winds	Improve weather forecasting for better predictability of storms, leading to better preparation and potentially less damages (early warning systems, disaster risk management)

(continued)

Table 9.1 (continued)

Relevant climate impacts	Impacts on road and rail infrastructure	Possible adaptation measures
	Disruptions and consequent safety and socioeconomic impacts	Emergency planning and evacuation routes omitting high-risk areas
	Leaf fall may be concentrated, decreasing rail security/adhesion	Wind fences for open rail infrastructure
	Increased occurrence of lightning strikes to rail signalling or electronic systems	For overhead lines: circuit breaker protection
	Lightning strikes disrupting electronic signalling systems, e.g. axle counters electromagnetic compatibility of railways	Adapt design standard for signalling equipment

This can seriously affect evacuation in the case of extreme weather events. The main adaptation measures, then, include:

- more resilient design standards and materials for infrastructure construction;
- improved drainage systems;
- regular maintenance of all infrastructure;
- urban planning that avoids high risk areas;
- minimising the need for road/rail infrastructure through compact urban planning; and providing sufficient redundancy to allow for alternative ways of passage when obstruction occurs

9.3.2 Vehicles and Operations

Public and private vehicles and their services need to be adapted in order to function reliably under climate change. Adaptation of public transport and informal paratransit are especially important because they are the only motorised mobility options for large parts of developing city populations. Moreover, it is important for public transport services to remain attractive for those who can afford private motorised mobility in order to avoid modal shift towards more emission-intensive transport.

Table 9.2 gives an overview of relevant climate impacts on vehicles and operations, as well as their corresponding adaptation measures.

The vulnerability of the transit system to climate impacts should ideally be considered in the planning phase. Planning for public transport must also be closely integrated with planning for road infrastructure in order to design an efficient and resilient system. Moreover, it is important to consider that public transport plays a key role in disaster risk management and evacuation planning. The consequences of failing to properly integrate public transport services into evacuation plans was bitterly demonstrated during Hurricane Katrina in August 2005.

Table 9.2 Summary of key climate change impacts and adaptation responses for vehicles and operations (ODPM 2004; Transportation Research Board 2008; Wooler 2004; Woolston undated)

Relevant climate impacts	Impact on vehicles or driving conditions	Possible adaptation measures
Increased temperature and more heat waves	Increased temperatures in busses and trains possibly leading to passenger and driver discomfort and heat exhaustion	Sufficiently large opening windows
	Driver discomfort and exhaustion can lead to heightened accident levels	Tinted windows to shade off the sun
	May lead to shifts from public to air-conditioned private transport if resources allow or to air-conditioned taxis	White painted roofs
	Use of more costly and more energy-intensive air conditioning systems	Improved thermal insulation and cooling systems
		Air conditioning, ideally using systems without F-gases (if available and affordable)
		Driver training
		For overhead buses: design standard for power supply to meet anticipated demand within the life of the system (especially higher demands due to increased air conditioning) and withstand higher wind speeds
		For underground rail: develop hot weather contingency plans
		Include new design standards in public procurement requirements of the public transport fleet
	Wearing off or melting of tires Overheating of equipment, such as diesel engines	New design standards may be needed to withstand higher temperatures (this will have to be communicated to/ undertaken by the national level)
More extreme rainfall events and flooding	More events of difficult driving conditions with implications for safety, performance and operation, *e.g.* speed restrictions causing delays	Manage speed limits in bad weather conditions, *e.g.* reduce the running speed of trains

(continued)

Table 9.2 (continued)

Relevant climate impacts	Impact on vehicles or driving conditions	Possible adaptation measures
	Flooding of the public transport fleet, causing economic damages	Drivers of public transport vehicles should be appropriately trained for extreme weather conditions, such as heavy rains, hail and wind Planning for emergency routes Early warning systems to evacuate high-risk areas Flood insurance
More intensive and frequent storms	More events of difficult driving conditions or impossibility to drive, as well as derailments or collisions leading to disruptions and consequent safety and socioeconomic impacts	Driver training
	Overturning of vehicles or trains	Speed restrictions Improve weather forecasting for better predictability of storms, leading to better preparation and potentially less damages (early warning systems, disaster risk management) Emergency planning and identification of evacuation routes omitting high-risk areas

Residents of New Orleans without access to a cars were left behind with little relief or guidance from public authorities (Litman 2006; Renne 2005).

9.3.3 Mobility Behaviour

Changes in behavior can be expected during adverse weather events. Empirical studies point to slower traffic speeds during rainfall events that lead to delays and disruptions, the most severe impacts occurring during peak hours and on already congested routes (Koetse and Rietveld 2009). This is particularly relevant for many large cities already suffering from traffic congestion.

Adverse weather can also lead to less walking and cycling trips, at least beyond a certain trip length. This can encourage a shift to motorised transport (where those modes are available and affordable) and severely impede the overall mobility of urban residents who rely on walking and cycling. For short trips, on the other hand, the impacts of extreme weather are expected to be rather low. This underlines the importance of dense urban design, which can reduce travel demand and exposure to adverse weather impacts. In regions where hot weather reduces the attractiveness of cycling and walking, green and blue spaces offer a multi-purpose solution. Lakes and rivers, for instance, can have a cooling effect on the urban microclimate and improve infiltration (countering floods). Trees planted alongside walkways and bicycle lanes can also provide shade while improving the micro-climate, increasing attractiveness and acting as a minor carbon sink.

9.4 Taking Action on Adaptation

Providing information and raising awareness of the need to start adaptation today are important to improve the capacity and the acceptance of both decision-makers and society. Since the adaptation of urban passenger transport cannot be limited to simple technical fixes, it requires the behavioural change of transport users and a shift of thinking in planning approaches. Convincing municipal government officials across departments of the relevance of adaptation is a prerequisite for any successful adaptation strategy. In many cases, this will require training key personnel and identifying so-called ‘adaptation champions’ who will push the adaptation agenda within their departments.

City governments need to consider the effects of climate change in relation to particular departmental responsibilities (e.g., rail, roads or housing) but must also work across departments in order to develop an effective and integrated strategy. A balance should be found between providing access to mobility for all, increasing resilience and limiting greenhouse gas emissions.

Different groups of actors are in a position to act on distinct aspects of mobility. Transport planners, then, should interact with each, including, e.g., spatial or city planners, climate change experts, flood and disaster risk managers, transport providers, vehicle suppliers and civil society.

Climate change considerations must be integrated into the general transport system design, new transport developments, as well as maintenance activities of existing transport networks and emergency planning (Fig. 9.1).

Three basic approaches to adaptation can be identified: retreat (or avoid), protect, or accommodate.

Whereas *retreating* from areas at high risk from climate hazard may be a measure of last resort, in a planning context, retreat means *avoiding* development in these areas in the first place. This may also be the cheapest option (Fig. 9.2).

Protection can include both hard measures (e.g., sea walls or drainage) and soft measures (e.g., parks for cooling and infiltration, or the protection of mangroves to buffer storm surges). Whereas protection measures are often ‘external’ solutions,

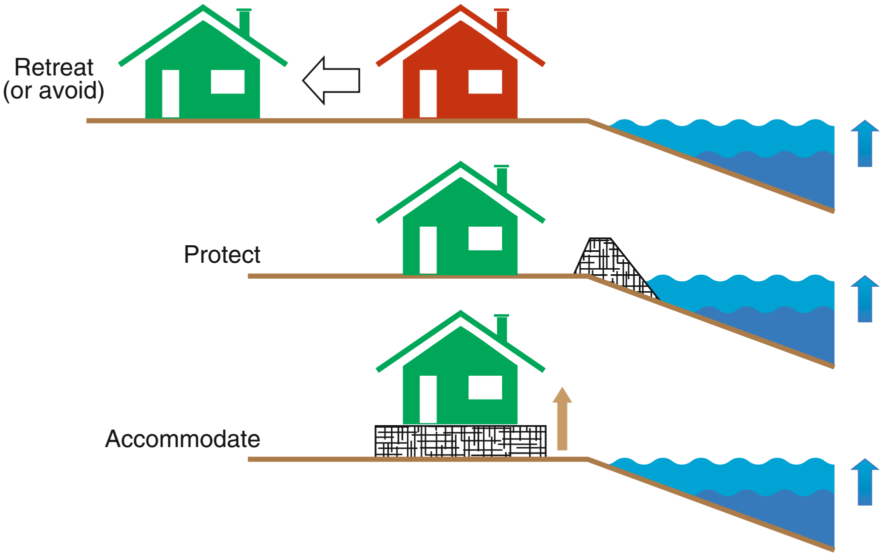

Fig. 9.1 Three fundamental approaches to adaptation (Eichhorst 2009)

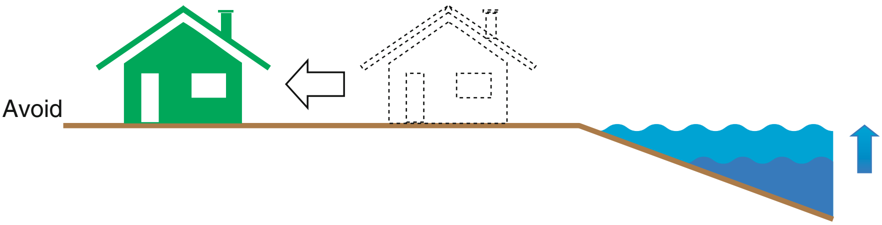

Fig. 9.2 Avoiding high risk areas for new developments (Eichhorst 2009)

accommodation means adapting the transport system or infrastructure itself. Accommodation also includes both hard measures (mostly infrastructure and vehicles) and soft measures (e.g., emergency bus routes).

9.4.1 A Framework for Climate-Proofing Transport

Transport planning and operations need to take current and future climatic changes into account. This means that new tools need to be integrated into transport planning. In particular, the assumptions built into models for long-term transport planning have to be revisited and potentially adjusted.

Climate change adds to the dynamics of urbanisation and increases the uncertainty involved in decision-making. Designing robust transport policies or projects aims to create transportation systems that function well under a range of potential global warming scenarios, rather than creating the most efficient system for a precisely specified set of assumptions. Studies have shown that we now know enough to develop plausible scenarios (Dessai et al. 2009; ECA 2009) in order to make informed decisions, which can significantly reduce vulnerability.

To create a high-quality and reliable transport system, decision-makers should carry out a multilevel planning process. To promote climate-proof urban transport design, mitigation and adaptation strategies need to be integrated into the transport planning process.

Largely based on the approach developed by the UK Climate Impacts Programme (UKCIP), seven important steps can be recognized for developing an integrated adaptation strategy for urban transport development. Figure 9.3 illustrates the process steps and how they integrate into the main steps of transport planning and decision making.

These steps can be equally applied to individual investments and maintenance decisions, mobility concepts in urban areas, comprehensive transport master plans, as well as ex-post climate proofing of existing transport networks and infrastructure (for details on each of the process steps please refer to Eichhorst 2009).

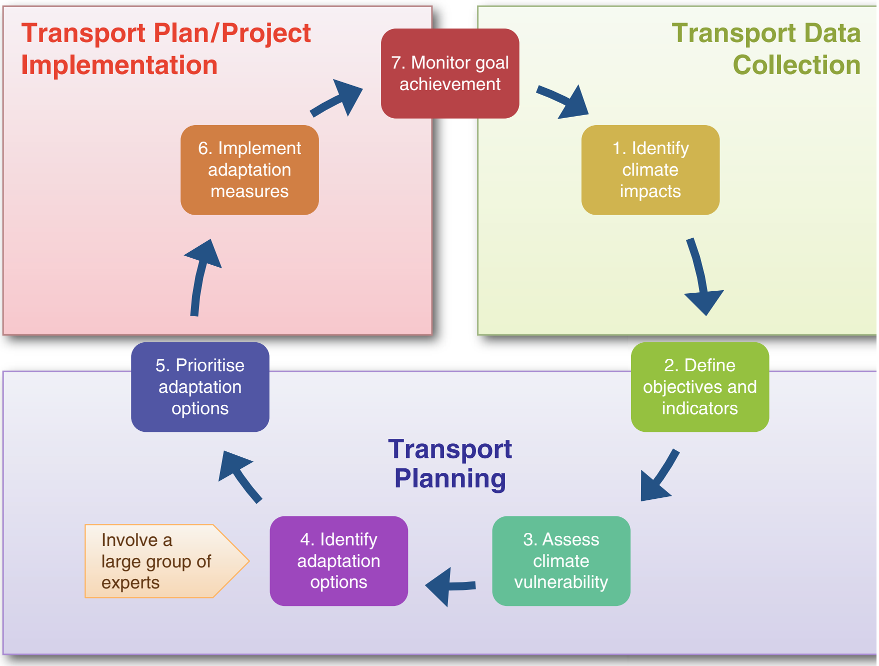

Fig. 9.3 A framework for developing an adaptation strategy for urban transport development (Eichhorst 2009)

9.5 Conclusions and Outlook

In many developing cities, the impacts of extreme weather events on urban transport systems have already been severe. This was seen, for example, in the September 2009 flooding of Manila, when the city's major thoroughfares were rendered impassable by flash floods. This event illustrates the importance of developing more resilient sustainable urban transport systems, especially as impacts are expected to worsen. To be truly sustainable, the transport system must work for all, including the urban poor. This will require addressing current deficiencies in informal settlements.

If vulnerabilities of the urban system within developing cities are to be minimised, adaptation of urban transport must be addressed in the larger context of transport needs. Further work is needed on clearly defining realistic steps towards achieving climate-proof, pro-poor and affordable urban transportation systems in developing cities. For instance, more specific design standards suitable for developing countries are needed.

Adaptation and mitigation measures should be pursued in parallel as transport accounts for 23% of energy-related CO_2 emissions globally (IEA 2008) and is one of the few sectors in which emissions are actually growing. Adaptation to climate change in the transport sector has to be seen in the framework of climate proof urban design. This means that the transport sector should be made both resilient *and* as low-carbon as possible. Only if both aspects are tackled can the risks of climate change be minimised.

Significant synergy potential between adaptation and mitigation measures can be identified in compact and transit oriented city planning. These include: minimising travel demand, reducing transport infrastructure and transport emissions, using green spaces and rivers for cooling, infiltration and higher attractiveness, and the development of climate proof design standards for infrastructure. Still, more research is needed to better understand synergies and trade-offs between adaptation and mitigation measures in transport.

There is an urgent need to allocate financial resources to adaptation planning and implementation at the city level. This may be achieved through tapping local, national and international finance sources. Ultimately, each city must identify the specific adaptation needs of its constituency. Local knowledge will help to make better projections and risk assessments possible. Development of good-practice case studies for adaptation in urban transport and exchange of existing experiences with planning for, and management of, extreme weather events in developing cities should be encouraged. More efforts are also needed in integrating disaster risk management more closely with transport planning.

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Part III
Frameworks for Local Action – Challenges and Proactive Recommendations

Chapter 10
Introduction: Frameworks for Local Action – Challenges and Proactive Recommendations

Olivia Tusinski and Alice Balbo

As a relatively new field, the tools, language, and conceptual frameworks associated with adaptation to climate change are still in a state of development. Institutional and academic focus on adaptation has traditionally been grounded in rural settings and conceived in terms of disaster risk management and response, technological innovation, and the implementation of 'hard' solutions to pending climate impacts. While focus has since shifted to climate-related impacts in urban contexts, the problem of urban adaptation remains largely defined as a physical one, concerned with protecting the built fabric and urban form of cities. A great deal of attention has focused on the fortification of critical infrastructure – roads, bridges, urban drainage systems, coastlines – to protect against rising sea levels, flooding and drought, heightened temperatures and other impacts associated with climate change.

While technological/physical solutions are a crucial piece of the adaptation puzzle, there is growing recognition of the role that social, economic and political forces play in enabling or inhibiting urban resilience to climate change. The emerging prominence of vulnerability concepts, community-based adaptation approaches, inter-institutional learning, and collaborative frameworks illustrate a shift toward 'softer' approaches within the mainstream adaptation discourse.

A number of presentations and panel sessions held at the Resilient Cities 2010 Congress concluded with a call for more inclusive approaches to adaptation governance. The contributions contained within this section revisit the unique range of perspectives that emerged around this broader theme. These provide insight into how new collaborative frameworks might be shaped by sharing examples of how inclusive governance, local participation and multi-level, multi-sectoral linkages have been integrated into new research methodologies, policies and practices.

Each contribution highlights the crucial role that local governments play in the development of effective adaptation strategies by emphasizing the need to be as inclusive as possible in their planning processes. This means motivating stakeholders

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to actively participate in the decision making process, as well as fostering a more pro-active role for academia and closer cooperation between researchers and practitioners.

Consensus has also emerged through criticism of existing planning, consultation and assessment paradigms. Many of the authors question the validity of scientifically based risk assessments, dependency on capital-intensive infrastructure, and the emphasis of risk perception on physical hazards rather than the vulnerabilities associated with human systems and social factors. They further highlight the difficulties of bridging science and practice and implementing collaborative research in the absence of a ‘common language.’ This is not to suggest that each author shares the same normative perspectives. The issue of leadership, for instance, is a key area of divergence; whereas some authors identify municipal departments, others place councilors or communities at the house-hold level as the most crucial component of collaborative processes and partnerships.

While some of the following contributions point towards best practices, they also stress that adaptation needs vary according to the particular challenges faced by local governments, and that one-size-fits-all approaches do not apply to all barriers and drivers of climate change adaptation.

The following chapters provide a basis for re-examining the conceptual approach to adaptation, particularly with respect to collaboration, experimental thinking and forms of knowledge-sharing. They do so by critically engaging with the *who* and the *what* of adaptation; that is, the predominant modes of planning, consultation, and response associated with adaptation, as well as the scope of actors who should be feasibly involved. Each provides proactive recommendations and examples, illustrating the variety of conceptual tools and approaches available to bridge the divide between knowledge and action.

Chapter 11
Inclusive Adaptation: Linking Participatory Learning and Knowledge Management to Urban Resilience

Michaela Hordijk and Isa Baud

Abstract Uncertainty, unpredictability and change have become key characteristics of today's interdependent world. Although risks, disasters and crises are inherent to human existence, the speed, frequency and scale at which they occur today are unprecedented. Natural disasters related to global warming have increased in the last decade. Although climate change is considered a global problem, its impacts are felt locally. Cities, then, must respond earlier and more effectively to risks and hazards. Although both 'resilience thinking' and 'community based adaptation' have made headway, they have been mainly applied to rural areas and natural resource management at regional levels within social–ecological systems. This paper applies the lessons of resilience thinking and experiences in community-based adaptation efforts to urban areas.

The paper argues that participatory knowledge management systems can enhance resilience in urban areas. Participatory knowledge management systems equip stakeholders at the local level to deal more effectively with sudden change, risks, and long-term stresses. Simultaneously, they can foster social capital and trust, strategic leadership, and enhance collective competence – all important components of resilient systems.

Keywords Adaptive urban governance • Knowledge systems • Participatory knowledge management • Resilience • Risk

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11.1 Introduction

For cities to be prepared for climate change, they need to develop in a sustainable manner, based on resilience and enhancement of their adaptive capacity. Participatory learning and knowledge management is an essential instrument to promote such adaptive capacity for resilience. In a new EU-funded research programme called Chance2Sustain, we will analyse how fast-growing cities in developing countries can direct urban governance processes toward increased resilience and adaptive capacity, by integrating social, environmental and economic growth concerns, and by supporting their efforts in participatory spatial knowledge management.[1] In this paper, we take up the basic question underlying the thinking of Chance2Sustain, namely, how participatory learning and knowledge management can contribute to cities' greater adaptive capacity.

The basic assumption behind the programme is that cities need to combine their economic growth strategies with environmental concerns and social inequality issues, in order to produce more resilient patterns of development. Essential instruments include different kinds of knowledge, patterns of governance with a variety of actors (including local communities), and different patterns of financial support. Fast-growing cities come from differing political and economic conditions, and their development processes reflect this variety. Therefore, the programme utilizes a comparative approach based on the case studies of ten fast-growing cities in four countries to analyze their different processes and outcomes.

11.2 Resilience and Adaptive Capacity

The concept of resilience has evolved rapidly in recent years. In 2001 the Intergovernmental Panel on Climate Change (IPCC) defined resilience as 'the degree to which a system rebounds, recoups, or recovers from a stimulus' (IPCC 2001: 894). In their Fourth Assessment Report it is defined as 'the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change' (IPCC 2008: 233–234). The ICPP reports exemplify the

[1] The full title of this research programme is 'Urban chances – city growth and the sustainability challenge. Comparing fast growing cities in growing economies'. Funded under the 7th EU-framework programme (Project no. 244828), the programme partners include the European Association of Development Research and Training Institutes (EADI), Germany; Amsterdam Institute of Social Science Research, University of Amsterdam, The Netherlands; French National Center for Scientific Research (CNRS), France; School of Planning and Architecture (SPA), India; Cities for Life Forum (FORO), Peru; Centro Brasileiro de Análise e Planejamento (CEBRAP), Brazil; Norwegian Institute for Urban and Regional Research (NIBR), Norway; and the University of KwaZulu-Natal (UKZN), South Africa. For more information on the research programme see: http://www.chance2sustain.eu/.

evolution of the concept from its original, static definition in physics and ecology (the time needed to return to a state of equilibrium after a shock (Manyena 2006) into a somewhat more dynamic concept. However, efforts 'to retain the same basic structure' are not necessarily an optimal response when the previous situation consisted of very uneven and inequitable distribution of risks stemming from climate change and their effects (Dodman et al. 2009).

More recent approaches define resilient systems as not only having the capacity to rebound or adapt, but also the potential for sustainable development because they can respond to and shape change in a manner that does not reduce future options. Intrinsic to this approach is that resilient systems provide capacity for renewal and innovation in the face of rapid transformation and crises (Berkes et al. 2003).[2] The Asian Climate Change Resilience Network characterises resilient cities as those which 'create, enable, and sustain the services and institutions required for basic ongoing survival and are characterized by their ability to generate new opportunities for their residents. They avoid relying on solutions that depend on anticipating specific hazards, and instead take a broader, integrated approach' (Dodman 2010). The alliance identifies four core principles on which resilience of cities is based: redundancy,[3] flexibility, capacity to learn, and capacity to reorganize (Dodman 2010). In our research programme, we consider resilient development to be a combination of:

- economic growth patterns that combine a focus on international competitiveness through, e.g., large-scale economic projects with support for local small-scale enterprises (which are the backbone of the city economy, providing the majority of local employment);
- social policies addressing poverty and inequalities, particularly those related to slum areas and their residents;
- environmental policies addressing basic service provision (brown agenda) and ecosystem sustainability (green agenda) – particularly those related to water and energy use supported by two essential instruments for city governments and their stakeholders;
- fiscal autonomy and taxation capability for funding of city policies as well as fiscal capacity and accountability of spending;

[2] See also Norris et al. 2008 'Resilience is a process linking a set of adaptive capacities to a positive trajectory of functioning and adaptation after a disturbance' (Norris et al. 2008: 130).

[3] Redundancy refers to the extent to which substitutions are possible in the event of disruption or degradation (Norris et al. 2008: 131). When applied to urban systems, for instance, it can refer to alternative energy resources, redundancy in transport possibilities and/or roads, or communication systems. It always implies that alternative systems can take over in case the main system fails. Redundancy in urban governance networks is less straightforward. It is important that alternative actors can take over if the main actor fails to act in a crisis (see our paragraph on strategic leadership). However, redundancy in urban governance networks introduces the risk of unclear or overlapping possibilities, paralyzing rather than fostering key stakeholder initiatives.

- participatory learning and knowledge management, focusing on the types of knowledge recognized and the networks through which it is generated and used to increase the adaptive capacity of cities.

Early efforts to increase cities' resilience have focused on making hard infrastructure more resistant to the anticipated effects of climate change.[4] Recent approaches focus more on the capacities of actors, institutions and governance networks to deal with stresses and sudden shocks – i.e., the *adaptive capacity* of cities (Godschalk 2003). Such actors include local government, the private sector and local communities. Community-based adaptation (CBA) is an interesting new approach as it represents a community-led process, based on communities' priorities, needs, knowledge and capacities – a process that should empower people to plan for the impacts of climate change. The difference with existing community-based approaches is that CBA takes the potential impact of climatic change on livelihoods into account by using lay *and* scientific knowledge (Reid et al. 2009: 13; Scott and Barnett 2009; Pelling 2003).

Aspects of adaptive capacity such as flexibility, the capacity to learn and the capacity to reorganize can conflict with planning and 'command and control' management approaches. Several recent trends in urban governance – such as decentralization, the shift from government to governance and increased citizen participation – in principle allow for greater flexibility, autonomy and creativity at the local level. However, the internal efficiency and outsourcing on which 'New Public Management' thinking is based can pose an obstacle to building more resilient urban planning and management processes. They potentially undermine the capacities of cities to deal with future risks by relegating redundancy, flexibility, and creativity to marginal and non-economic processes, reducing their capacity to increase resilience (Baud and Hordijk 2009).

For Chance2Sustain, we have identified several key factors that enhance adaptive capacity and resilience. These are analyzed in our city case studies:

1. The absolute and relative amounts of 'capital', be it economic resources and technology, financial capital, human capital through information and skills, social capital in trust, social networks, and strong institutions (cf. IPCC 2001: 893)[5]
2. Governance approaches, with special reference to the responsiveness of decision-making at appropriate subsidiary levels, and the inclusion of different

[4]Resistance strategies are most appropriate for known dangers, which are likely to happen with some frequency and can be anticipated. They are far less appropriate to deal with 'unknown unknowns' (Longstaff 2005 cited in Norris et al. 2008: 132).

[5]It is interesting to note that Norris et al. (2008) listed very similar aspects of what they labelled primary sets of adaptive capacities; namely, economic development, social capital, information and communication and community competence. In their definition, 'to build collective resilience, communities must reduce risk and resource inequities, engage local people in mitigation, create organizational linkages, boost and protect social supports, and plan for not having a plan, which requires flexibility, decision making skills and trusted sources of information that in function in the face of unknowns' (Norris et al. 2008: 127).

social actors (local communities as well as private sector enterprises of different sizes) (Pelling and High 2005)
3. Interactions between actors and networks at and within different scale levels (Baud and Hordijk 2009)
4. The extent of common understanding of the urban system among different stakeholders (Abel et al. 2006: 16).
5. The capacity to combine and integrate different forms of knowledge (Lebel 2006: 19; Reid et al. 2009; Scott and Barnett 2009)

11.3 Participatory Learning and Knowledge Management

In our Chance2Sustain research programme, we integrate the issues taken up in the programme through the main concept of 'participatory learning and knowledge management.' Although earlier studies acknowledge different forms of knowledge, our intention with the Chance2Sustain research programme is not only to distinguish the different types of knowledge required for urban resilience, but also the processes by which this knowledge is produced, recognized and prioritised (by political negotiations between actors). In Sect. 11.4 we will go into how participatory learning and knowledge management can be utilized.

11.3.1 Types of Knowledge, Production and Recognition

Generally, scientific/technical knowledge is broadly recognized as a necessary tool for urban planning and management. However, resilience thinking and CBA emphasise the need to combine and integrate different forms and types of knowledge (Bizikova et al. 2009).[6] Other types of knowledge include tacit knowledge from work experience, embedded environmental and economic sector knowledge, social knowledge at the neighbourhood and city-wide level, as well as 'lay'-generated scientific knowledge (Miranda and Hordijk 1998; Coaffee and Healey 2003; Van Ewijk and Baud 2009). Sources of knowledge from knowledge institutions such as socio-economic surveys, sectoral knowledge based on practice, and remote sensing images in GIS are still not used systematically. Such types of knowledge are particularly relevant in identifying spatial concentrations of particular (economic) growth processes, social inequalities, and environmental hazards (Baud et al. 2008, 2009, 2010). These provide information on where interventions are most needed, and what

[6]For instance, long-term predictions from climate change models need to be combined with local knowledge on specific trends already experienced to produce a localised understanding of risks (Reid et al. 2009).

combination of issues exists at any one location. Such disaggregated knowledge can provide useful support for political and community discussions within urban governance networks, enabling decisions to be motivated by knowledge of issues rather than a priori political preferences.

The essence of participatory knowledge production and recognition is that multiple stakeholders provide a variety of knowledge sets that can be integrated through co-learning and management. Scott and Barnett (2009) identify processes in which 'lay' scientific knowledge is generated for negotiations on the environmental effects of large companies on community health. Community-based adaptation uses existing participatory appraisal techniques (such as seasonal calendars, timelines and trend-analysis that provide insight into changes experienced), community mapping and transect walks (to identify resources and risks), and ranking (of vulnerabilities and hazards, and coping and recovery strategies) (Reid et al. 2009). Tools specifically relevant for participatory knowledge management work with mental models (identifying drivers of climate change), and participatory mapping techniques (combining local knowledge with insights from remote sensing observations such as Google Earth, mapping information and knowledge in GIS) (Gaillard and Maceda 2009; Reid et al. 2009; Baud et al. 2010), and participatory scenario building (Bizikova et al. 2009). However, an important limitation is that participatory knowledge generation often remains a one-time effort (Adger et al. 2005). Knowledge production needs to be continuous and interactive, and utilized pro-actively, in order to become a form of participatory knowledge *management* that can foster community resilience.

11.3.2 Knowledge Management Modes and Participation

The ways in which knowledge management contributes to local development processes has been outlined in research on sustainable rural development (where extension processes are important). Drawing from that literature, the following modes can be distinguished that incorporate non-expert knowledge in different degrees (cf. Bruckmeier and Tovey 2008). In the 'knowledge incorporation' approach, the specific qualities of local user knowledge are recognized, and strategies designed to strengthen producer knowledge. This is compatible with participatory methods of knowledge management. In the 'elitist' model, scientific and expert knowledge is considered valid only, and local user knowledge is given little priority. It implies that managerial-bureaucratic systems dominate in implementing strategies for ecological modernisation. Bruckmeier and Tovey distinguish a third model called 'knowledge embedding,' which acknowledges the social construction of knowledge and the conflicts surrounding what knowledge is accepted by actors in a network. It is followed by a model of 'political governance,' which suggests that knowledge management is mainly based on the political power behind the organisations providing the ideas for ecological changes. What Bruckmeier and Tovey find emerging from their case studies, is an 'adaptive management and polycentric management model.' Through this, resource users and producers build up local capacity, utilizing opportunities for joint learning and collective formulation of strategies, and shared decision-making processes, with formal and informal groups (Bruckmeier and Tovey 2008: 323).

The main conclusion to be drawn from these various models is that different types of knowledge are not necessarily accepted in a harmonious process, but need to be negotiated. Such processes are local, regional and international, and interact in unexpected ways, through the politics and power networks behind them. It remains important that local communities are recognized as producers and users of knowledge, and as politically relevant stakeholders in governance networks. In the following section, we bring together the issues of resilience and adaptive capacity with participatory knowledge management.

11.4 Participatory Knowledge Management and Resilience: An Integrated Model

The extent to which participatory knowledge management can foster resilience in urban planning and management differs according to local situations. In the Chance2Sustain project, we will analyse ten cities to discover which factors hinder or contribute to more participatory knowledge management processes for increasing urban resilience. Towards this end, we have developed a model linking actors and capacities in multiple ways and across scale levels.

Earlier models developed to analyze disaster preparedness are useful as a basis for this discussion. They suggest that resilience emerges from *a set of networked adaptive capacities*; namely, economic development, information and communication, and social capital and community competence (Norris et al. 2008: 135–144). However, a model used to analyze participatory knowledge management in urban resilience should include some additional factors. These include strategic leadership, linkages between different scale levels, and more explicitly, the issue of social inequalities. Together, this provides the following model (see Fig. 11.1).

We agree with earlier models that economic development and the equitable distribution of its benefits create the essential resource base for resilience. Therefore, the Chance2Sustain programme explicitly analyzes different urban economic growth strategies. However, in order to assess the potential outcomes of these strategies, economic growth needs to be considered alongside patterns of *social inequality* and those policies that address it. Likewise, the ecological context has to be taken into account.

Information and communication are often highlighted as building blocks of resilient systems (IPCC 2001; UN-Habitat 2007; Prasad et al. 2009). Not only do we need different types of knowledge as discussed above, but sources of information need to be trusted (Longstaff and Yang 2008; Norris et al. 2008). In participatory knowledge management processes, such trust is created when different sources of information are interactively acknowledged, validated and transformed into a shared understanding of reality.

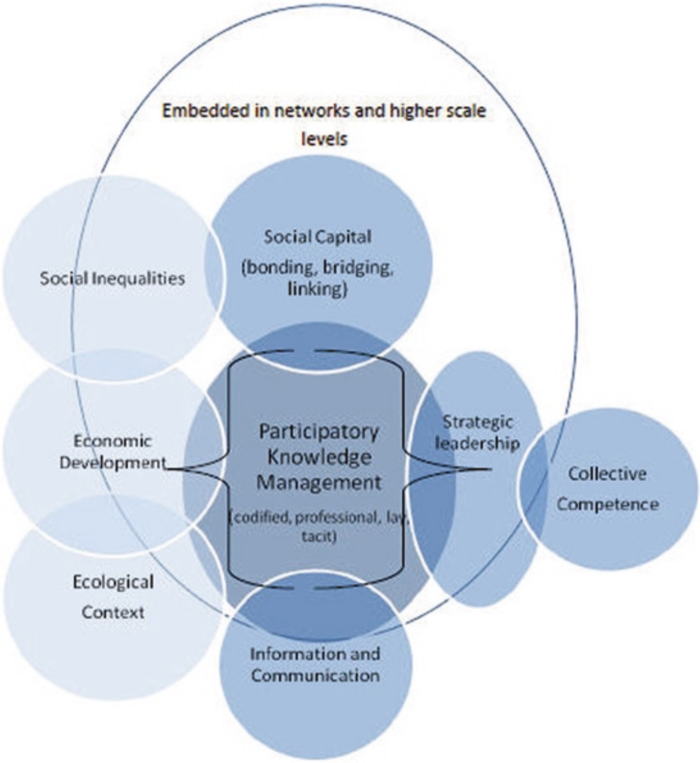

Fig. 11.1 Building resilience through participatory knowledge management (Based on Norris et al. 2008)

Social capital has been labelled a public good that potentially reduces transaction costs, facilitates information exchanges, and enhances innovation and the capacity to learn. It has also been linked to the collective capacity to manage knowledge (Pelling and High 2005: 316). The process of joint knowledge generation simultaneously strengthens existing social bonds (bonding social capital), and creates new social capital. Creating links between different communities within and between cities (bridging social capital) is equally important. For increasing the resilience of communities and cities, linking social capital is also strategically important.[7] Participatory processes create interfaces and foster informal linkages between community members, leaders, local government officials and other stakeholders. If maintained – for instance, through the regular interaction necessary to update the

[7]Bonding capital refers to social ties among people with a shared identity, i.e., homogeneous groups. Bridging capital refers to ties between groups with differing identities (heterogeneous groups) but with shared objectives. Linking social ties refers to vertical links, for instance between communities, leaders and government institutions.

knowledge base – these linkages can form a stock of latent social capital that can be rapidly drawn upon when swift action is needed.

‘Hubs’ or ‘super-connected’ members in these networks are crucial leaders, especially when they link different networks (Longstaff 2005; Norris et al. 2008). Yet the role of such ‘key-stones’ or positions of *strategic leadership* have hardly been studied. Therefore, the Chance2Sustain programme will focus on the pathways through which social capital and strategic leadership in participatory knowledge management enhances collective competences.[8]

Finally, urban resilience relies upon the linkages between local governments and their own communities, as well as linkages with outside communities, higher levels of government and the private sector.[9] Local governments are key actors in fostering resilience in urban areas, with primary responsibility for many of the services urban households need. They also form the links with higher scale levels of government and the private sector.

When urban networks are drawn into wider networks for strategic policy development towards disaster prevention and promotion of long-term resilience, their views need to go beyond their specific responsibilities. This promotes a ‘culture of safety’ in which government networks anticipate the effects of sudden shocks and strategies to deal with them, including response, recovery and mitigation/adaptation methods (Aguirre 2006). To develop synergy, urban governance networks should work on a continuous basis, providing training and support, and include the whole set of stakeholders in scenario planning exercises to increase future adaptive capacity. Resilience thinking contributes to such an approach by incorporating ecological, social, and economic systems, as well as spatial scales, temporal changes, and situational diversity.

As outlined in Sect. 11.2, local workshops provided the basis for developing reports on the issues contributing to resilient development within each of the ten cities studied through Chance2Sustain. Further fieldwork by the teams of researchers and practitioners in the ten cities will provide information on the extent to which processes of participatory learning and knowledge management exist and provide support to strategies for resilient urban development in the future. The results will be laid down in policy briefings, briefings for communities in the local language and academic articles. A final international conference will include a comparative report on the total results, and will be shared with policy makers and communities at both the regional and European level. Platforms for stakeholders, such as those provided by ICLEI, offer a strong forum for sharing the programme’s results.

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[8] Norris et al. (2008) defined ‘community competence’ as ‘the networked equivalent of human agency’, hence the capacity for decision making and meaningful collective action. Prerequisites for these capacities are critical reflection and deliberation, and creativity and flexibility (Norris et al. 2008: 136). We label the capacity of governance networks of various stakeholders ‘collective competence’.

[9] A clear exception is the participatory vulnerability analysis (PVA) developed by Action Aid, which starts at the community level, but also feeds into district, national and international levels (Reid et al. 2009: 27).

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Chapter 12
Urban Adaptation Planning and Governance: Challenges to Emerging Wisdom

JoAnn Carmin, David Dodman, Linda Harvey, Shuaib Lwasa, and Patricia Romero-Lankao

Abstract Numerous recommendations are emerging to guide cities in developing risk assessments and climate adaptation plans. In some instances, these recommendations are appropriate. However, since many are drawn from traditional approaches to comprehensive planning and from climate mitigation programs, they often do not account for the unique challenges associated with urban adaptation or provide guidance that is sensitive to the distinctive social, cultural, institutional, and administrative characteristics of particular locales. In this paper, which captures a panel discussion convened at the Resilient Cities Congress 2010, expert practitioners and academics review emerging wisdom about best practices in adaptation planning, draw on their experience and research findings to challenge these assumptions, and show what we can learn about process and outcomes from cities at the forefront.

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12.1 Introduction

Urban governments and professionals are increasingly recognizing that climate change poses a wide range of threats to the built environment, natural systems, and human populations. In response, some cities are beginning to engage in adaptation planning and implementation. These early climate adaptation initiatives are paralleled by the efforts of intergovernmental organizations, NGOs, development professionals, urban consultants, local civil society, and funders to generate and disseminate information about best practices to representatives of municipal governments and departments. In many cases, these groups conceptualize adaptation as a linear process initiated with scientifically-based risk assessments and resulting in the implementation of capital intensive infrastructure solutions such as new dykes to prevent coastal inundation from sea-level rise, new dams to improve water supplies, or new drainage systems to reduce flooding. In other cases, priority is placed on strengthening local capacity to deal with climate variability and change, with a particular focus on enhancing household, community and urban resilience. Emerging wisdom also suggests that cities need to engage international networks, funders, and NGOs in order to identify best practices, create plans and implement their actions through participatory, multi-disciplinary, and community-based adaptation processes.

The views and recommendations being advanced are rooted in traditional planning models and ideas gleaned from climate mitigation programs. In some instances, these practices may be appropriate and relevant. However, in many cases they do not capture the best available knowledge about mitigation, let alone account for the unique challenges and opportunities associated with urban adaptation. For instance, in contrast to the practices being advocated, recent research suggests that the generation of detailed scientific analyses, consultant-driven vulnerability assessments, and broad-brush strategies can impede rather than advance action. In addition, there is mounting evidence to suggest that ideas promoted by international experts frequently conflict with local agendas and therefore fail to garner widespread support or to meet critical needs, and the uncritical application of participatory and community-based processes may have the unintended consequence of more firmly entrenching existing inequities in cities. In this session, we examined emerging wisdom related to scientific knowledge, best practices and planning processes, participatory governance, and mainstreaming in light of current research findings and city experiences in order to advance a more nuanced understanding of how urban adaptation can be initiated, implemented, and sustained. The following sections reflect highlights and key arguments which emerged from short presentations delivered by panelists.

12.2 Science and Urban Responses to Climate Change

The prevailing view is that climate science is influential and should be used to guide climate agendas and activities at the urban scale. However, the movement from knowledge to action is not as straightforward as many suggest. This is the case for two key reasons. Firstly, high levels of uncertainty surround knowledge about climate impacts, vulnerabilities, and thus adaptation options and constraints. For instance, science cannot currently help policy makers know, with any certainty, how much is too much (e.g., what is the point beyond which emissions are too high). Science also cannot objectively ascertain at what level human interference with climate becomes dangerous and impairs society's capacity to adapt, even in those urban areas where current capacities to adapt are high. Some form of value judgment is unavoidable. And, value judgments are context specific, not only because climate impacts and vulnerabilities differ from place to place, but also because people perceive risks in diverse ways (Gupta and Asselt 2006).

Secondly, in contrast to prevailing wisdom that action is shaped by knowledge, factors such as mental (cultural) models, power, and institutional settings mediate the interactions between science, decision making, and action in the local climate arena. This is clear in the way resources are allocated across the science-policy interface, which rather than being driven by projected climate challenges is determined by the institutional values of the involved players and their historic patterns of spending and action. Further, despite the presence of research from the social sciences pointing to the need for integrated programs of action, many adaptation initiatives fail to account for the linkages between climate change and vulnerabilities resulting from uneven urban development and inflexible governance structures (Moser 2009; Satterthwaite et al. 2009; Romero-Lankao 2008).

12.3 Planning and Uncertain Best Practices

Over the years, international NGOs, associations, and networks have assisted cities, often by disseminating best practices, creating tools, and initiating demonstration projects. Given the success of these types of efforts in the past, many organizations are promoting these same approaches to climate adaptation. More often than not, the ideas they are advocating reflect general views about climate planning, models derived from comprehensive planning, or summary lessons about adaptation that have not been subjected to comparative or critical assessment. In contrast to the emerging wisdom, recent studies demonstrate some of the ways planning and implementation vary in cities at the forefront of adaptation. As we learn from the pathways cities are following, it is clear that they are adopting different approaches based on the distinctive features, capacities and constraints of their locale (Carmin et al. 2009; Bicknell et al. 2009; Roberts 2008; Romero-Lankao 2008; Burch and Robinson 2007). Therefore, rather than promoting a single model of adaptation, the trends in research findings suggest that it is imperative to identify variations in pathways so that cities can pursue approaches that support their goals and are aligned with their particular administrative, social, cultural, and political contexts.

12.4 Local Participation and Urban Governance

Municipal authorities in many developing countries are emphasizing the need for government-driven strategies as a first step in addressing climate impacts. Despite appreciation in many circles about the value of participation and democratic modes of governance, there are notable disparities in emerging best practices. On the one hand, municipalities are focusing on internal government dynamics and developing plans and programs based on input that is derived solely from municipal departments. On the other hand, there are calls for increased participation at the community scale (e.g., Polack 2008). This is particularly true for those working with urban poor communities since they largely shape the fabric of many urban spaces in cities in developing countries, and are often highly vulnerable to the effects of climate change, particularly because of their greater exposure to hazards and lower levels of adaptive capacity (Dodman and Satterthwaite 2008). At the same time, these groups are given few opportunities to participate and influence policies. Broader participation by these groups has the potential to increase the efficiency of development programs, present valuable alternative voices, and facilitate meaningful social change (Mohan 2002). The following sections outline two related approaches, both placing an emphasis on how local participation in climate adaptation can be galvanized and contribute to enhanced urban governance, that are emerging to counter municipal-centered approaches to adaptation planning.

12.4.1 Action Research

One approach being applied in a number of contexts is action research. This method provides opportunities for city authorities, academics, communities, civil society organizations and private sector actors to interact and engage in a process of learning by doing (Akera 2007; Pennington 2008). Through their exchanges, urban actors pool expertise, resources, and knowledge as they search for solutions to local problems (Lwasa and Kadilo 2010). Action research has ignited engagement among urban actors in assessing climate change risks and developing local level strategies for adaptation. In this process, communities are involved in conducting assessments and designing solutions while engaging with city authorities in order to ensure realization of outcomes. The generation of neighborhood-scale adaptation measures through this process can provide important insights and lessons about how to prepare for the impacts of climate change.

12.4.2 Community-Based Adaptation

Community-based adaptation (CBA), is a relatively new strategy that relies on many of the same principles as action research, but is oriented to strengthening the capacity of local people to adapt. CBA is based on the premise that local communities have the skills, experience, local knowledge and networks to undertake locally appropriate activities that increase resilience and reduce vulnerability to a range of factors including climate change (Ayers and Forsyth 2009). In CBA, adaptation strategies are generated through participatory processes involving local stakeholders. To date, CBA interventions have been predominantly rural, reflecting its origins in community-based natural resource management, and have focused on issues such as livelihood diversification. The potential for CBA in urban areas often is simultaneously over-stated and underestimated: while small-scale responses cannot adequately meet large infrastructural needs, communities do have an important role in developing local infrastructure and shaping political decisions (Satterthwaite et al. 2009). To function effectively in urban areas, CBA approaches will require a deeper and more critical analysis of broader social and power relations (see Few et al. 2007) in order to address the need for capacity strengthening in communities and the removal of the adaptation deficit. Its recognition of the importance of local involvement and engagement in decision-making processes provides CBA with the potential to support forms of adaptation planning and governance that take the needs of low-income groups into account.

12.5 Mainstreaming Adaptation

Adaptation actions are critical to creating resilient, sustainable cities. However, injecting climate considerations into decision-making is a challenge given the range of social, economic and environmental issues competing for attention and support. The prevailing wisdom is that mainstreaming can be achieved through sequential, linear approaches (Checkland and Scholes 1999). However, cities are finding that they need to rely on non-linear, non-mechanistic processes that account for complexity, variability, and uncertainty. For many, this will mean changing from forecasting to back-casting since historical conditions will no longer be accurate predictors for planning, maintenance and upgrades. While adaptation actions are consciously or unconsciously underway throughout municipalities, mainstreaming will require alterations in management approaches so that adaptation forms a programmatic course of action that is consistent with and can be readily addressed in the context of existing plans, systems, and routines (Lee 1993).

12.6 Conclusion

As summarized in this paper, the panel discussion reviewed the experiences that cities in the global north and south have had in planning and implementing climate adaptation action. The themes emphasized in the course of discussion point to the need for social science research that investigates activities taking place in cities and evaluates the emerging conventional wisdom. Rather than demonstrating the viability of a "one-size fits all" approach rooted in assessments and following a linear or sequential sequence, the evidence presented in the panel suggests that in order for adaptation to take root, measures need to be appropriate to the specific context. This does not mean that models and guidelines for cities to follow cannot or should not be generated. Instead, it suggests a need to identify and acknowledge variation emerging in adaptation measures, the outcomes achieved by these different approaches, and the context to which each is best suited. It is also necessary to strike a balance between the very real need for urban infrastructure (particularly in low-income nations) and the needs of low-income and marginalized groups. By taking more nuanced and systematic approaches, we can support the use of both expert and local knowledge while promoting robust forms of urban climate governance.

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Chapter 13
Urban Climate Change Adaptation in the Context of Transformation: Lessons from Vietnam

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Abstract The imperative of adapting cities to risks associated with climate change will reveal the strong potential of political and administrative action at the level of local urban governments. Action at this level facilitates adaptation solutions that are closely linked to the specific needs, wants and capacities of local communities and economies. At the same time, the need to adapt to climate related impacts creates new, and in many cases, unprecedented challenges for local governments, often exceeding their current capacities in terms of risk awareness, expert knowledge, access to information, finance, or legal responsibility. This paradox is most apparent in emerging economies that have recently undergone, or are currently experiencing, political and economic transformations, including (re-)orientation towards market-oriented economies, administrative liberalisation, decentralisation, dynamic urbanisation and changing socio-political paradigms. Drawing on empirical research based on coastal and delta cities in Vietnam, focusing particularly on the example of Can Tho City in the Mekong Delta, this paper analyses the challenges local urban governments face with respect to formulating and implementing climate change adaptation strategies for their city in the context of transformation. The paper argues that challenges are particularly evident in the fields of urban growth and expansion, administrative reform and decentralisation, the fragmentation of sector responsibilities, the broadening of the actor spectrum and planning and management paradigms. Lessons learned can be utilised for other local urban governments experiencing similar conditions. Knowledge gaps and future research needs are also explored.

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13.1 Urban Climate Change Adaptation: Imperatives and Specifics

Projected global climate change scenarios provide strong imperatives for cities and urban agglomerations to adapt to the impacts entailed by these changes. For good reason, much attention has been directed towards adaptation in rural areas – influenced mainly by the argument that climatic changes, and particularly changes in hydro-meteorological conditions, are felt most directly by agriculture-based rural communities dependant on stable ecosystems. However, it is becoming increasingly evident that urban adaptation also requires increased attention. From a global perspective, cities experience high degrees of exposure to climate change-related hazards – around 360 million people, for example, live in coastal urban areas less than 10 m above sea level (McGranahan et al. 2007), considerable proportions of which are located in regions with intense cyclone activity. Urban areas further have a high potential for triggering combined or cascading hazards of both natural and human origin (Bull-Kamanga et al. 2003; Kraas 2003). At the same time, they constitute nodal points that host key functions for larger scale economic, political and social systems (for a more detailed analysis see Olorunfemi 2009; Kraas 2007; Birkmann et al. 2010).

Adapting cities and urban agglomerations to the threats of climate change implies substantial challenges as well as opportunities, determined by the particularities of urban systems. The most important challenges relate to the size, density and often rapid growth of cities (with the latter being particularly prevalent in the global South). Moreover, cities are often characterised by high degrees of internal man-made hazards, such as pollution, health risks or social segregation which can exacerbate social vulnerabilities and reduce the baseline resilience of many urban population groups with regard to climate change adaptation (Pelling 2003). Cities are also characterised by a high level of persistence in terms of their built environment, making physical adjustments difficult and costly. Yet high urban quantities and densities in terms of population, infrastructure and key functions can be seen as one of the greatest opportunities for fostering the implementation of urban adaptation measures. They facilitate high degrees of efficiency as well as the (political and public) acceptance of costly and far-reaching adaption measures for and within cities. Furthermore, the issue of climate change adaptation bears considerable potential for increased future awareness, funding and action in the domains of national budgets and international development assistance.

Adaptation has been understood as an 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (IPCC 2007). As the greatest effects of climate change are yet to be experienced (Smit and Wandel 2006; Smithers and Smit 1997) learning from experience can only offer limited guidance. Climate change adaptation must therefore deal with different dimensions of uncertainty related to the bio-physical domain (quality, quantity, speed and location of climatic changes and resulting hazard) as well as to socio-economic and cultural aspects (e.g. with respect to future developments in a given socio-economic system influencing climate change vulnerabilities and the capacity to respond to climate hazards) and finally, cognitive and psychological dimensions (e.g. with respect to the accepted levels of risk or the acceptance of adaptation strategies) (Dessai et al. 2007; Garschagen and Kraas 2010). Decision making under such conditions requires robust strategies which are able to accommodate alternative possible futures (Dessai and Hulme 2007) and provide no-regret solutions (Smith et al. 1996) which are desirable given their wider contributions to resilience-building even in the case that expected hazards do not strike (Allenby and Fink 2005; Adger et al. 2005). At the same time strategies need to be flexible to allow for adjustments when new information becomes available. In this context, Tschakert and Dietrich (2010) argue for a shift in paradigm, away from the understanding of adaptation as a (one-off) implementation of (often technical) measures or practices and towards an understanding of adaptation as a continuous process which requires the development of adequate tools for anticipatory and dynamic learning. Birkmann et al. (2010) call for a stronger focus on the development of adaptive planning and governance systems addressing governance and management procedures in addition to the (currently prevalent) emphasis on adapting physical infrastructure, while often leaving governance and management procedures untouched. The extent to which such approaches can be undertaken in the urban sector of a given country ultimately depends on the (highly complex and dynamic) nature of urban adaptation governance.

13.2 Urban Governance, Transformation and Decentralisation from a Global Perspective

Over the last two decades, the discourse revolving around governance has gained substantial influence in both scientific and political spheres (Doornbos 2001; Eander 2002). Despite the fact that over time various different schools of thought have developed with varying analytical foci and underlying norms, epistemologies and/or ontologies (e.g. Pierre and Peters 2000; Grindle 2007; de Alcántara 1998), some common elements can be found in all of these schools that allow for defining governance as all ways in which individuals and institutions exercise influence and manage common affairs at the interface of the state sector, the private economic sector and civil society. It thereby comprises both the formalised and informal mechanisms through which actors articulate their interests, exercise their legal rights, meet their obligations and/or mediate their differences (adapted from UNDP 1997).

Albeit the original focus on nation states within governance discourses, a widening spectrum of actors influential to the management and planning of urban affairs has influenced the shift of attention to governance within local urban contexts (Einig et al. 2005). The shifts and fragmentations of power associated with governance at this level are particularly evident in countries undergoing broader political, economic and social transformation.

Decentralisation reforms (particularly during the 1980s and 1990s) have in this context been significant factors increasing the tasks and responsibilities of local governments, especially in urban areas (Hall and Pfeiffer 2000; Bardhan and Mookherjee 2006; Stren 2003; Crook and Manor 1998).[1] It has been argued, on the one hand, that decentralisation offers opportunities to empower local populations and actor groups (Stren 2003). On the other hand, decentralisation has proved to generate substantial problems if (financial, technical and human) resources are not adequately augmented in line with the decentralisation of tasks and responsibilities (Elander 2002; Bovaird and Löffler 2002). This type of decentralisation and resulting problems can in particular be observed in countries with political systems favouring strong central control (as in the case of the Socialist Republic of Vietnam). When states with central governments eager to preserve tight regimes are simultaneously engaged in decentralisation efforts, the political fabric and power landscape is particularly complex and contested.

13.3 Vietnam: Challenges to Urban Climate Change Adaptation in a Transforming Country

The challenges specific to local urban climate change adaptation in Vietnam are deeply embedded in a wider context of transformation and urbanisation in the country, which affects (current and future) urban management, planning and governance. The inter-linkages between this wider context and the urban level shape the basis for analysing urban adaptation to climate change. For the purposes of this paper, the implications of urban growth and expansion, administrative reforms and decentralisation, fragmentation of sector responsibilities, a broadening spectrum of stakeholders and planning and management paradigms will be examined.

13.4 Urban Growth and Expansion

In association with comprehensive economic liberalisation reforms (doi moi) from a centrally-planned towards a market-oriented economy since the mid-1980s, Vietnam's cities have experienced substantial growth over the last decades which is expected to intensify in the future. In 1985, less than 20% of the country's population lived in urban areas, accounting for some 11.5 million people. By 2009, the figure rose to nearly 30%, equalling over 26 million people (UN DESA 2008). The urban population in Vietnam is expected to double by 2035 and will account for 57% of the country's population by 2050 (UN DESA 2008). Against this backdrop, a rapid geographical expansion of cities and towns into their peri-urban and rural

[1] Decentralisation endeavours may often be understood in relation to structural adjustment policies largely determined by the Washington Consensus and/or by political and economic transitions (e.g., in the context of post-socialist states).

hinterland is occurring. An estimated 10,000 ha is transformed annually from rural to urban land use (Coulthart et al. 2006), thereby decreasing retention areas for river floods and precipitation drainage, and placing pressure to expand into low-lying and vulnerable areas. The rapid sprawl and densification of Vietnam's cities and towns has outpaced local and national capacities to provide adequate infrastructure development, particularly related to transportation, drainage, sewage, housing and sanitation infrastructure (Coulthart et al. 2006).

13.4.1 Administrative Reform and Decentralisation

In order to respond to these ongoing changes and to shape future transformations in the fields of land management, planning and construction, a number of comprehensive legislative reforms were passed in the early 2000s.[2] In addition to changes in the domains of land use rights and planning guidelines, these reforms entail substantial decentralisation of tasks and responsibilities to province and district level, particularly in the areas of developing, outsourcing and approving development master plans, land-use plans, construction plans and sector development plans.[3] The reforms open up opportunities for effective urban development measures and climate change adaptation strategies that are custom-tailored towards local requirements and constraints, accepted by local administrations and open to engagement by the local public and business sector.[4] Empirical research in Can Tho City and Ho Chi Minh City, however, has revealed that local level governments are insufficiently equipped to respond to the task of formulating local adaptation action plans as requested by the National Target Programme to Respond to Climate Change. This is due to a lack of awareness of climate change issues, a lack of sufficient information and data sharing between local and higher-level governmental agencies, a lack of human resources (appropriate qualifications and training), a lack of financial resources with which to conduct modelling work or hire external consultants, and finally a lack of time and resources to engage in such additional work beside the day-to-day management of the cities.

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[2] The most important cornerstones are the new Law on Land, the Law on Construction (both effective since 2004), an Amendment to the State Budget Law of 1996 (2002) and more recently the Law on Urban Planning (effective since 2010) (for a more detailed overview see Garschagen 2009; SRV 2002, 2003a, b, 2009).

[3] The detailed rights and responsibilities of different administrative levels in the planning and particularly the approval process are differentiated along the lines of the six administrative grades into which urban areas in Vietnam are classified as well as along threshold values for investment volumes, geographical extent of projects and level of detail for the respective plan (compare SRV 2003a, b, 2009).

[4] One interviewee, a department leader in a province level planning agency under the People's Committee in Can Tho City (Mekong Delta), for example, mentioned that "policy making at Ministry level in Hanoi, often lacks a detailed understanding of the Mekong Delta and Can Tho City, and measures proposed in the past have therefore too often been characterised by limited effectiveness and feasibility."

13.4.2 Fragmentation of Sector Responsibilities

Urban climate change adaptation in Vietnam touches upon three quite separate domains of policy-making and administration, namely urban management and planning, official climate change response and disaster risk management. Each of these domains is coordinated by different focal agencies, i.e. sector ministries and their local branch departments at province and district levels. The development or outsourcing of urban master plans is supervised mainly by the Departments of Construction. In theory, this process should be linked closely to land-use planning under the Departments of Natural Resources and the Environment (DONRE) and to the overall socio-economic development planning under the Departments of Planning and Investment. However, ongoing research suggests that these planning branches often work independently, implying a lack of synchronisation and the production of parallel and sometimes conflicting plans.

Disaster risk management traditionally falls under the responsibility of the Departments of Agriculture and Rural Development. This is due to the fact that natural hazards are mainly considered to be a rural issue and that water-related hazards are predominantly managed by hydraulic infrastructure which often serves a double purpose of irrigation and flood control. However, climate change response – as a fairly new field in the political landscape – has been decided to be coordinated by the DONREs (even though in theory other departments are envisaged as member of the local climate change adaptation committees to be established). This clear-cut assignment indicates that climate change risks are mainly conceived in terms of physical hazards (and this is reflected by the demarcation of institutional responsibilities) rather than vulnerabilities associated with human systems. A direct result of this perception is a strong focus on fighting physical events rather than adjusting the socio-economic preconditions that influence vulnerabilities.

13.4.3 Broadening of the Actor Spectrum

Associated with the general liberalisation and transformation policies of the last decades, Vietnam's urban areas are increasingly influenced by private sector forces, which are shaping not only development projects, but also entire planning procedures – from general zoning and building regulations to specific construction and master plans. Thus the spectrum of actors playing an active role in planning processes and in shaping future directions of urban development has experienced a partial power shift out of state agencies into the hands of the private sector – and most importantly into hybrid modes constituted by more or less informal or even illegal alliances between the two. Furthermore, while recent legislative reforms formally call for strong public participation in planning processes,[5] research has

[5] Public participation is encoded in various paragraphs of legislation calling for input to planning processes and feedback on draft versions of urban master plans.

revealed that these mechanisms are rarely used and that local officers often have a limited awareness of or interest in the implementation of these directives.

13.4.4 Planning and Management Paradigms

Rooted in a long history of taming nature, e.g., converting large delta areas into productive agricultural land through drainage, irrigation and flood control infrastructure, Vietnam has traditionally followed a control-oriented and technocratic paradigm when it comes to dealing with natural hazards – and now increasingly climate change related hazards (Garschagen 2010). This means that physical response measures such as dyke systems or sluice gates have been perceived as the preferred – if not exclusive – adaptation option to date. Yet, with growing discussion on climate change adaptation in scientific and political circles and increasing exchange between Western and Vietnamese researchers, the debate on soft approaches to resilience and adaptation is slowly gaining momentum in Vietnam. However, in many cases this is a rather hollow discourse with a lack of clarity on both sides as to how conceptual notions can be translated into concrete adaptation strategies for the country's cities.

13.5 Discussion, Conclusions and Outlook

Based on the example of Vietnam, this paper has attempted to discuss the struggles that local urban governments, especially in countries undergoing comprehensive socio-economic, political and administrative transformation, face in developing and implementing climate change adaptation strategies. The decentralisation of responsibilities within urban planning and management can offer significant opportunities for shaping context-specific, effective and widely accepted measures if local stakeholders are equipped with sufficient resources to realize and mediate this process. As climate change adaptation in cities will have to be enacted first and foremost at the local level, lessons learned from the analysis of current shortcomings can provide valuable guidance for necessary adjustments and improvements with regard to administrative processes, management paradigms and governance mechanisms. Research in Vietnam suggests that greater attention needs to be paid to the changing actor-power-landscape. Related power shifts must be acknowledged and the respective actors involved during the process of developing (formal) adaptation strategies.

The example of Vietnam further illustrates the risks associated with allocating responsibility for climate change to a single sector, rather than installing it as a cross-cutting theme to be addressed within the future planning and management efforts of many if not all sectors of local urban governments (e.g. health, transportation, economy, social affairs). Countries with rather static government and management paradigms are likely to have difficulties in developing, testing, and implementing innovative approaches and paradigms necessary for urban climate change adaptation. This hurdle is even greater if those paradigms are coupled with hierarchical government structures, as in the case of Vietnam. Research in Vietnam has shown that within these conditions, local governments hesitate to pursue new or unconventional strategies, as they have not been tested in the past and come with the risk of meeting disapproval at higher levels. Local governments feel particularly intimidated when being overstretched by tasks demanding resources beyond their means, including sufficient knowledge and experience.

In order to stimulate new directions, it is necessary to break the prevalent divide separating conventional adaptation strategies associated with formal governmental efforts (particularly physical protection infrastructure) and other, more informal adaptation strategies at household or company level. The latter should be integrated into official adaptation schemes. Such informal or experimental strategies have been insufficiently addressed in the discourse surrounding urban adaptation strategies; conceded informality can be seen as an intermediate, experimental stage in probing new solutions.

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Chapter 14
Getting Ready for a Changing Climate: Supporting Councillor's Leadership Role in Adaptation[1]

Joyce Wei Ka Lee

Abstract Adapting to climate change means adapting the way we do things – in all areas of our lives – to respond to the changing circumstances (Department for Environment, Food and Rural Affairs (Defra), What is adaptation? http://www.defra.gov.uk/environment/climate/adaptation/what.htm 2008). Adaptation is fundamentally a local issue – flooding, coastal erosion, agricultural patterns, employment, regeneration and land use all impact the local level. It is now recognised that local governments have an important role in grappling with the complex impacts of climate change and setting in motion plans for their services and communities.

Councillors (elected members) play a key role in championing adaptation at the local level. Their ongoing enthusiasm in driving forward the green agenda, their awareness of the risks of business as usual and their passion for community wellbeing puts them in the best position to develop public awareness of, and the political will, for taking action on adaptation. This paper identifies councillors' leadership role in the adaptation agenda. It presents a checklist with five suggested actions for councillors. On communicating the adaptation agenda to the public, councillors could use more simple language, give practical examples and use more innovative channels of communications. On supporting their councils to take action, councillors could present a business case for adaptation and help build partnerships for delivery.

Keywords Adaptation • Councillors • Leadership • Communicate • Improve

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14.1 Introduction

Adapting to climate change means adapting the way we do things – in all areas of our lives – to respond to the changing circumstances (Defra 2008). The carbon that has been emitted over the past 100 years and continues to be emitted today will lead to changes in the UK climate for at least the next 30 years. Changing behaviour in response to these changes and their related impacts is known as adaptation to climate change. Whether climate change will mean more regular floods or hotter summers, our homes and economy will need to be more adaptive or resilient.

Adaptation is fundamentally a local issue: flooding, coastal erosion, agricultural patterns, employment, regeneration and land use all impact at the local level. It is now recognised that local government have an important role in grappling with the complex impacts of climate change – both risks and opportunities – and setting in motion plans for their services and communities.

Councillors (elected members) play a key role in championing adaptation at the local level. Their ongoing enthusiasm in driving forward the green agenda, their awareness of the risks of 'business as usual' and their passion for community well-being puts them in the best position to develop public awareness of and the political will for taking action on adaptation.

This paper identifies councillors' leadership role in the adaptation agenda. It presents a checklist with 5 suggested actions for councillors based on the discussions and ideas of over 30 councillors as part of the LGiU Climate Ready Learning Network on adaptation. This paper does not aim to provide all the answers to the challenges councillors face but aims to strengthen local and national debates on the adaptation agenda.

14.1.1 What Does Adaptation Mean?

The past 10 years have been the warmest decade recorded in 160 years in the UK (Met Office 2009). Past weather events like the heatwave in 2003, the floods in 2007 and the extreme cold and snowfall in the winter of 2009 have shown how weather can have severe impacts on council services and on people's lives. The snow in the winter of 2009 and 2010 caused chaos to public transport, social service delivery and waste collection services across the country. In areas such as Gloucestershire, Hull and Lincolnshire, the summer floods in 2007 left almost half a million people without mains water or electricity (Pitt 2008). Around 80% of the businesses were badly affected as a result of the floods in Cockermouth in November 2009 (Cumbria Intelligence Observatory 2010).

In June 2009, the UK Government released UK Climate Projections 2009, a detailed set of climate projections and the possible changes occurring with them between now and the end of the century. According to the projections, winter rainfall is likely to increase by around 10–20% in most parts of the UK by the 2080s. In south-east England and west Scotland, we could see 20–30% more rain

(UKCP09 2009b). The changes are different across different parts of the UK but the climate projections show that on the whole we will see hotter and drier summers, and warmer and wetter winters. The projections suggest that the UK could also experience sea level rises as high as half a meter in some areas by the 2090s (UKCP09 2009a).

14.2 Communicating to the Public

Language surrounding adaptation to climate change and related concepts can be difficult to understand, with academics and experts using technical terms. To ensure the public has a good understanding of what adaptation actions they can take, it might be helpful to consider how climate change impacts, or adaptation, is communicated to the public. Councillors could use more simple and straightforward phrases, for instance.

The phrase 1:1,000 year flood aims to show the probability of an event happening. However, probabilities can be different from reality, which makes them difficult to translate into decisions. Similarly, the wording of adaptation responses such as green infrastructure can be difficult for householders to understand. It may be more simple and straightforward to use phrases such as irregular and unpredictable weather events and green areas and open space.

14.2.1 Give People Practical Examples of What Communities and Councils Can Do to Adapt

> There is this incredible inertia amongst the public and we have to get the message across to them. (Cllr John Connor, Chichester District Council)

Councillors come face to face with people less motivated to take action on climate change and who do not consider it a priority. Some people find adaptation a daunting task because they are concerned about its effectiveness and high costs, which are difficult to justify in a recession. By using examples of adaptation to demonstrate effectiveness and value for money, councillors can get the adaptation message out to the public.

Councillors can speak with more authority and credibility about adaptation by presenting examples that have been implemented by councils and communities and the benefits of these adaptation actions. This could encourage communities to change their perception and behaviour. While more research is required into establishing cost-effective adaptation solutions, there are some good examples of actions already taken by councils and communities to adapt to climate change (Table 14.1).

Table 14.1 Community and council actions on adaptation

Manage flood risks	Gloucestershire County Council has been actively involved in raising awareness of flood risks so the public can take individual action to adapt. This includes developing a flood information pack, promoting flood defence products and campaigning on specific issues, such as disposing of fat, oil and grease in an appropriate way to prevent clogging up the drains and increasing the risk of flooding. (Gloucestershire County Council 2010)
Prepare for disasters	A research project in Rio de Janeiro, Brazil shows that low-cost retaining walls made with old tyres can effectively prevent landslides during rainy seasons. With less than one-third of the cost of conventional retaining walls and a huge supply of disused tyres in the area, a wall was built with tyres packed full with earth. The walls were proven successful when they resisted a torrential rainfall and protected hillside slum communities. (International Development Research Centres 1999)
Diversify crops	To seize the opportunities of a changing climate, Otter Farm in Devon is growing a diverse range of crops from olives and peaches to more traditional peas and asparagus so that whatever the weather conditions, there will always be some crops that will thrive. (South West Climate Change Impact Partnership)
Create green space	Manchester City Council planted trees in deprived areas. It also increased the number of green roofs on buildings across the city. The benefits included rain and surface water absorption, reducing the risk of flooding, reflection of heat, and the release of moisture to cool down the city. (CAG Consultants 2009)
Ensure water efficiency	Reigate and Banstead Borough Council and Surrey County Council are involved in a project that aims to reduce water demand in social housing. Water savings are made through changing the features of individual homes, a school and a leisure centre, such as installing sustainable showers and toilets and collecting rain water to use for toilets and washing machines. (Waterwise 2009)
Conserve biodiversity	Lancashire County Council's ecology service holds biological data for the area as well as advice on development control and planning matters. The Council also maintains a system that manages heritage sites of importance to the habitats, species and geological or landscape features. (Lancashire County Council 2010)

14.2.2 Use More Innovative Channels of Communication to Reach Out to the Public

> It's one thing to have the political aspirations in your plan, but making that work from the ground … is where leadership comes in … it's our day-to-day contacts that tell the public what their authority is really like. (Cllr Edward Collict, Lewes District Council)

With day-to-day contact with their constituents, councillors are best placed to reach out to the public. The use of conventional means of communication such as surgeries, letters, emails, council plans, websites and newsletters may not be enough to reach out to and engage with the public on adaptation. Some groups in the community may not use conventional communications due to a lack of interest or

Table 14.2 Getting the message out

Council website, newsletters and emails
Conventional methods of communication are still valuable as they are the first point of call for people who want to find out about council services. For example, information about adaptation could be posted on the back of council tax bills, service notification letters and parking tickets
Blogging and social networks
Some councillors are using the new social media by setting up their own blog or joining social networks, such as Facebook and Twitter, to engage with a wider group of people. The benefits include generating an interest around a topic, mobilising groups to take action, connecting with people not usually involved in public consultation and ensuring campaigns are more targeted
Face-to-face contact
Technology can be a cost effective way of reaching out to people but councillors have an innate desire to connect with people through face-to-face contact to build personal relationships and demonstrate commitment to addressing people's problems

access. To better connect with the public for the purpose of discussing adaptation, councillors could use more innovative ways of communicating, such as tapping into social media networks (Table 14.2).

Examples Staffordshire County Council developed an interactive website OC3 project to direct residents to up-to-date and reliable information about climate change. It outlines the predicted changes to the climate and links to local initiatives and blogs of interest to the public. The website also provides prize-winning games for people to take part and enables people to edit and update the website (Staffordshire Climate Change 2010).

airAlert is a service that informs vulnerable people, especially those with respiratory problems, of the daily air pollution level so they can make informed decisions before going outdoors. It sends a message through mobile phones, home phones, emails, webpages or RSS feed on computers (AirAlert 2011).

Cardiff City Council, Wychavon District Council and councils in Northamptonshire among others have been involved with organising "flood fairs" for residents and businesses to access advice and information on flooding and flood risk reduction, such as self help flood prevention devices.

14.3 Improving Your Council

> There are potential opportunities for local government to improve leisure facilities, to take advantage of climate change and to adapt to deal with extreme rainfall. (Cllr John Gardner, Stevenage Borough Council)

As with other decisions in council spending, a business case for adaptation is needed to demonstrate efficiency and justify the council's spending and priorities in times of spending cuts and growing demands on key services. Adaptation rates low on many council agendas, especially when compared to issues such as social services and housing. However, the reality is that adaptation will have direct impacts on these important council services. There is also an assumption that adaptation is all about managing risks and threats caused by impacts of climate change. In fact, opportunities arising from the need to adapt should also be considered.

Councillors as executive or committee members can work with their officers to present a business case for their council to adapt. For example, identify links between adaptation and existing performance indicators, sustainable community strategies and other local plans. Portfolio holders for adult social care, children services, housing, leisure, planning, tourism and transport could present the risks and opportunities of climate change to their services and the council could identify ways to adapt these services to function effectively. Members of scrutiny committees could also improve council services by carrying out a review of council's preparedness for past and future risks and opportunities.

Examples Hertfordshire County Council conducted research into the impacts of climate change on health and adult care services. The aim was to understand the risks and vulnerabilities of climate change across the council and to emphasise the importance of adaptation and the changing role of health and adult care services to cope with future changes. This research, along with other studies on adaptation, has influenced the Council's Corporate Plan 2009–2012 to make climate change a strategic priority (CAG Consultants 2009).

Kent County Council used the scrutiny approach to get buy-in across the council for climate change adaptation. Select committees were set up for both climate change and flood risk management. This helped increase and embed climate change awareness into the council's processes and planning (Energy Saving Trust 2008).

Oxfordshire County Council used the Local Climate Impacts Profile, a tool designed to assess exposure to weather and climate, to work out the cost associated with weather incidents over a decade, estimated to be £16.4 million. The project succeeded in raising awareness of adaptation internally and gathered evidence that the council was vulnerable to the impacts of climate change. Even though this figure was considerably underestimated, it lent weight to the adaptation agenda within the council (UKCIP 2010).

14.3.1 Support and Encourage Partnerships Between the Council and Relevant Organisations and Businesses to Deliver Adaptation Effectively

> We need to work together … we can't act in isolation. (Cllr Deborah Urquhart, West Sussex County Council)

Adaptation is difficult to achieve when working in isolation. For example, flood risk management remains a challenge for many local authorities partly due to a lack of effective partnership working and cooperation with relevant bodies such as water and utility companies. It is widely recognised that partnerships can be very effective at obtaining buy-in from relevant organisations, developing shared goals and priorities and apportioning funds and responsibilities. These activities can reduce the costs associated with solutions across boundaries and policies.

Councillors are diverse people, with links to community and voluntary organisations, private businesses and other local bodies. Given their community leadership roles, they could improve the council's work on adaptation by developing these valuable relationships between the council and relevant partners. With powers of decision making and scrutiny, councillors could encourage more and better partnership work between councils and other organisations so that responsibilities, funds and priorities on adaptation could be distributed more effectively.

*Example*s The Manhood Peninsula Partnership was initiated by residents of Chichester, and brings together bodies and organisations to look at adaptive ways to address the impacts of rising sea level. With West Sussex councillor Peter Jones as chair, the partnership brings together ten organisations including the Chichester District Council, West Sussex County Council, the Environment Agency, the Peninsula Community Forum and the Royal Society for the Protection of Birds to jointly bid for national and European funds, develop local projects and support local initiatives such as improving drainage systems (Chichester District Council 2010).

Lincolnshire County Council works through its Local Strategic Partnership to form the Lincolnshire Environment and Climate Change Action Partnership (LECCAP) that delivers climate change adaptation measures. LECCAP has produced and influenced a range of work including coastal management initiatives, catchment flood management plans, water cycle strategies and green infrastructure projects (CAG Consultants 2009).

14.4 Conclusion

Whether they will consist of heavier rainfall or hotter summers, homes, infrastructure and the economy will need to be better prepared against the potential impacts associated with climate change. For councils, this means considering protective measures as well as identifying areas of potential advantage or benefit. These actions can range from managing flood risks and using water wisely to identifying business opportunities in tourism or potential for the growth of new crops. It also entails ensuring that all service areas, such as transport and spatial planning, take climate projections into consideration. An understanding on the part of councillors of how climate change affects services can help councils to prepare and adapt. Their community leadership role is also very important in communicating the issues to the public.

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Chapter 15
Environmental Learning from the Ivory Tower to the Town Square: The Case of Trondheim, Norway

Annemie Wyckmans

Abstract Environmental learning in architecture and planning has shifted dramatically within a few years, from being an individual choice to becoming a collective responsibility and inherent part of professional ethics. Researchers, policy makers and practitioners face the challenge of improving the built environment's resilience to climate change and resource scarcity. This chapter argues for a more pro-active contribution from academic institutions, based on collaborative experiential learning, and three crucial elements including laboratory settings for facilitating creative exploration; intensive interaction between students and teachers; critical reflection of own and other's work. Knowledge brokerage activities based on these principles can trigger better, faster and more widespread environmental learning and knowledge transfer, leading to a more resilient built environment.

Using the Brøset development in Trondheim, Norway as a case, this article investigates the different roles academic institutions can play in sustainable urban planning, from consulting to facilitating collective learning among actors engaged with these challenges. The Brøset project consists of two parallel activities: firstly, an urban planning project led by the municipality, and secondly, an interdisciplinary research project at the Norwegian University of Science and Technology, funded by the Norwegian Research Council in cooperation with the Norwegian State Housing Bank and Trondheim Energy.

Keywords Collaboration • Environmental learning • Interdisciplinary • Knowledge brokerage • Mainstreaming

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15.1 A Pro-active Role for Academia

Environmental learning in architecture and planning has shifted dramatically from being an individual choice to becoming a collective responsibility and an inherent part of professional ethics. Educational institutions barely manage to cope with the wave of students and professionals demanding adequate courses, tools and guidance (Wyckmans 2008). Researchers, policy makers and practitioners daily face the challenge of improving the built environment's resilience to climate change and resource scarcity. They express a dire need for knowledge, best practice examples and tools that are able to combine environmental technologies with behavioural aspects such as lifestyle, housing patterns, transportation and leisure activities. Research shows that innovative technical solutions do not suffice; a change in lifestyle and professional ethics, stakeholder participation, and cross-sectoral collaboration are needed to provide the necessary societal and cultural drive to cope with climate change and resource scarcity (Cheng et al. 2008; Jones et al. 2009; WBCSD 2007). Despite ambitious political goals, planning a high-quality built environment sensitive to local resources and residents is no easy task for policy makers or researchers.

In an age that is urging for the mainstreaming of environmental issues in architecture, planning and all other domains of every-day life, academic institutions need to rethink the way in which they participate in the creation of a new type of professionalism. There is need for a new role for educational institutions and a new set of learning tools, not only in interaction with students, but with the entire building and planning sector. Rather than leaving it up to individual professionals to make an effort, there is need for collective learning mechanisms providing tools, examples and best practice transfer across the building and planning sectors. In this way, practitioners will be forced to learn more about and to dramatically increase the environmental performance of their projects on a regular basis.

In order to promote resource efficient architecture and planning, it is important that this type of design is being perceived as relevant and attractive for all practitioners – not only those with a particular interest in the subject. This type of challenge is the topic of a branch of behavioural science called choice architecture, extensively explored by Thaler and Sunstein (2008), amongst others. Choice architecture draws connections between the decisions people make and the manner in which problems are framed. The authors claim that people mainly choose the default option, unless they are especially engaged in the subject. This phenomenon, called the Status Quo Bias, is often used in product placement in supermarkets: placing groceries at eye level increases their sale in a predictable, easy and cheap manner, regardless of the type of product placed in this position. This chapter asks what the equivalent practice for resilience in architecture and planning would be.

Design routines are first learned in school, but maintained in practice through every-day decisions and activities. In order to boost the environmental performance of practice, therefore, it is of the utmost importance that practitioners are not only given the opportunity to be updated on environmental issues, but also indeed choose those alternatives and replace their design routines with more environmentally favourable ones when available.

Experiential learning is a learning method strongly advocated in the beginning of the twentieth century (Dewey 1998), the main aim being to learn decision making and problem solving skills by means of creative exploration, intensive interaction, and critical reflection as opposed to listening to lectures, for example. It is widely used in architectural and planning education, particularly in the design studio where students not only acquire the necessary design knowledge but also the appropriate professional attitudes (Nicol and Pilling 2000; Schön 1987). This type of learning environment provides a good opportunity for academia, practitioners and policy makers to cooperate across institutional and sectoral boundaries.

Policy makers are often restricted when it comes to shaping sustainable urban planning practice. Between minimum state regulations and relentless pressure from private developers, there are limited opportunities for creative exploration. A more extensive focus on the potential repertoire of design methods, solutions and experiences is called for. Often it is in the details of a project, in the connections between different professions that opportunities can be found for advancing the sustainability performance. In order to find this detail, there is a need for experts who are able to weigh the different perspectives of a wide range of actors incorporate them into a design that is meaningful for the local context. In addition, experts need to display the ability of critical reflection about their own role and about the premises for science and practice based experiences. The creative exploration of environmental issues in the built environment is challenging in a professional environment in which each hour and all use of resources have to be accounted for, leaving few opportunities for creative exploration.

Trying to advance beyond regulations is often depending on the personal drive of a few individuals within the organisation. This kind of ambition demands extra effort and makes the person more exposed to criticism. In that context, it is very inspiring for policy makers to meet researchers engaged in the same ambitions and link their scientific knowledge to the local political agenda. For researchers, interaction with policy makers is the best opportunity to have their research implemented in practice, even though it is not always academically meriting. Private developers are in some cases more ambitious than the public government; in others they are restrictive in their cooperation towards innovative environmental goals. There is need for an overview of and research into experiences with governance models in which different stakeholders mutually support each other to achieve ambitious policies and projects, and the kind of roles and interaction that show to be prolific in specific contexts (Evans et al. 2007).

The availability of a range of good examples and good experiences increases practitioners' probability of making environmentally benign choices in their own projects (Thaler and Sunstein 2008). However, 'architecture doesn't travel well' (Maritz 2008), and appropriate architectural and planning responses are necessarily also local and context-specific. It is not always clear which preconditions need to exist for a local sustainability process to produce tangible results (Evans et al. 2007). A deep knowledge of the history, geography and assets of the site is necessary to build upon the existing structures and dynamics of the area. In addition, individual experiential knowledge, gained in a particular context, may be difficult to communicate to external parties operating in a different framework (Gough and Scott 2007). For example, the power balance between municipalities and the State varies extensively in different countries. So does the relation between the municipality and private developers, and the availability of local research institutions. The transferability of others' experiences therefore always has to be balanced critically against the meaning of situated knowledge.

15.2 Case Study: The Brøset Project

This chapter describes experiences derived from the capacity-building activities developed during the Brøset project. The Brøset project, initiated in 2007 in Trondheim, is a framework for new knowledge surrounding sustainable resource use in local architecture and planning. The Brøset development forms a major component of Trondheim's participation in the Norwegian Cities of the Future project, a strategic government-run programme with focus on land use and transportation, energy use in buildings, consumption and waste, and climate change (Norwegian Government 2010; NTNU 2010). Compared to the rest of the Western world, Trondheim (and Norway) have a different starting point regarding resource use in the built environment. Norway exports oil and gas, and also has a high potential for biomass, wind and wave power. It produces the majority of its electricity by hydro power, which has also been traditionally used to heat buildings. However, due to rapidly increasing consumption needs, Norway needs to import fossil fuel power in winter. Combined with a vast petroleum industry and fossil-fuel based transportation, Norway's annual greenhouse gas emissions amount to about 55 MtCO2e (data for the year 2007), which is about 12 tCO2e per capita (Jones et al. 2009).

In the Brøset project, the interaction between urban form and lifestyle is used to reduce the urban carbon footprint. The project consists of two parallel tracks, the first an urban planning project led by the municipality, and the second a corresponding interdisciplinary research project at the Norwegian University of Science and Technology and Sintef Building and Infrastructure. Trondheim municipality leads the planning project, aiming to develop the 35 ha area into a high-quality carbon-neutral neighbourhood with local facilities such as kindergartens, nursing homes and green infrastructure, located 4 km from the city centre. The development is performed in close cooperation with site owners Norwegian State (Statsbygg and St Olavs hospital) and County of South-Trøndelag, rather than selling the site on the open market to the highest bidder. In 2009, NTNU started a corresponding interdisciplinary research project, Towards carbon neutral settlements – processes, concept development and implementation, in cooperation with Sintef Building and Infrastructure, Trondheim municipality, the Norwegian Research Council, the Norwegian State Housing Bank and Trondheim Energy (NTNU 2010). Different disciplines are involved including architecture and planning, industrial ecology, engineering and social sciences. In Summer 2010, a planning competition was announced in which four interdisciplinary teams were invited to transform the research knowledge into the practical development of the Brøset site.

15.3 Industry, User and Interdisciplinary Forums

This chapter discusses the different platforms created to place climate change and resource scarcity at the heart of the Brøset project and secure its ambitious goals in a life-cycle perspective. The creation of three forums – the industry forum, user forum and interdisciplinary forum, each targeting different stakeholder groups, create a learning environment in which attitudes, opinions and experiences regarding sustainability can be shared, examined, tested and updated (Kolb 1984). The state-of-the-art knowledge within each forum may lead in different directions, depending on the weight that is given by different actors to a range of parameters and the specific empirical context.

15.3.1 The Industry Forum

The industry forum contains a monthly breakfast seminar under the heading 'KLIMAX,' signifying the urgent and long-overdue contribution of architecture, construction and planning to climate change resilience and mitigation. During these seminars, researchers, policy makers and practitioners are invited to share and comment their professional experiences in dealing with climate change and resource scarcity. The target audience includes planners, architects, engineers, sociologists, product suppliers and so on. The breakfast seminars provide a low-threshold meeting place for actors from different sectors to discuss challenges that may supersede traditional professional boundaries. Starting at eight o'clock am each session includes two half-hour presentations by invited experts, followed by discussion. The platform is financed by the university to facilitate a broad professional platform for dialogue, reflection and collaboration. The topics and lecturers are chosen in cooperation with Trondheim policy makers and other stakeholders, related to the progress made in the Brøset project. The seminars are attended by 50–80 participants from academia, public organizations and the building industry.

15.3.2 The User Forum

Building confidence with the general public and end users in particular requires a well-balanced dialogue between experts, general public and end users, especially when a planning project contains a lot of uncertainties. The Brøset and Cities of the Future user forums ensure active involvement of potential residents, NGOs and other actors involved in defining what a low-carbon neighbourhood implies from an end user perspective. It involves the use of focus groups as well as dissemination of information to the general public by means of open evening lectures and articles in the local newspaper on a regular basis. In tight cooperation with Trondheim policy makers, researchers and students interact with residents, school children and interested citizens at town meetings, museum exhibitions and other public events early in the stages of the process onwards to avoid misunderstandings and to incorporate local knowledge as best as possible. The different forms of user involvement are carefully elaborated and documented.

15.3.3 The Interdisciplinary Forum

The interdisciplinary forum enables knowledge transfer among the researchers and policy makers involved in the project. Workshops are conducted with the aim of developing in-depth knowledge of best practice projects internationally as well as criteria for designing successful implementation processes in a local context. Regular seminars are organised for the participants to discuss how the deliveries of the different actors and professions involved in the project are to be merged into an interdisciplinary whole, with attention opportunities that arise between different professions and policy sectors. After each KLIMAX breakfast seminar, a meeting is organised between the guest experts, Trondheim policy makers and researchers to explore the topic more profoundly and discuss options for future cooperation. All meetings are attended by a research fellow at NTNU, who continuously documents and analyses the planning process at the municipality and its cooperation with the researchers.

15.4 Conclusion

Academic institutions have typically been looked upon as separate from society. Based on analysis and discussion of the activities and their preliminary outcomes of three communication platforms, this chapter advocates a more pro-active role for academic institutions in building resilient cities, widening their mandate to generate and facilitate critical reflection, creative exploration and the widespread brokerage of experiences in practice and research. The work done by NTNU in the Brøset project involves research, participation and experimentation. It has evolved into an exploration of practice planning and architecture involving numerous actors but also consuming more time and resources (during the planning and development stage) than traditional projects.

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Chapter 16
Plan B:altic: A Social–Ecological Approach to Climate Change Adaptation

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Abstract This contribution elaborates on the transdisciplinary research approach employed in the project plan B:altic which facilitates integration of practitioners throughout the entire research process. The project aims to show possible ways of developing adaptation strategies to climate change, to discuss jointly the transdisciplinary research and solution approach and to offer practitioners innovative suggestions. This paper focuses especially on preliminary experiences with the use of resilience thinking as a conceptual bridge between different disciplines and knowledge areas involved in the research process. Besides obvious strengths of the resilience concept such as addressing uncertainty, complexity and transformational change, its practical use as a guiding principle for developing adaptation strategies evokes a number of concerns, yet first and foremost the question of operationalization.

Keywords Climate change • Adaptation • Resilience thinking • Social ecological research • Transdisciplinary

16.1 Adaptation Research and Practice in Coastal Urban Areas

For some years now, research on adaptation to climate change has increased. The research project plan B:altic focuses on climate change and spatial development, particularly the adaptation strategies of urban and regional planning in urban regions of the Baltic Sea coast which, due to a concentration of population and infrastructure and economic functions (Ruth and Coelho 2007) may be particularly vulnerable to potential harmful effects of climate change. The project

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is funded by the German Ministry of Research and Education under its Social-Ecological Research Programme (2009–2013). The aim of plan B:altic is to formulate and implement integrated strategies and processes for sustainable urban and regional development. One of the challenges of responding to climate change at the local level revolves around uncertainty and knowledge limitations; one of the main drives of plan B:altic is thus to identify and discuss specific solutions for urban and regional resilience while initiating tangible processes at the local level.

Future climate projections are complex and characterized by uncertain cause-and-effect relationships and incomplete or inconsistent scientific or historical evidence (Overbeck et al. 2008). Adger and Tompkins (2004) suggest building resilience as one way of dealing with such uncertainties surrounding future risks. Resilience can be understood within the context of sustainable development as the ability of socio-ecological systems to persist and evolve mainly by incorporating change, while being confronted with unpredictable and sudden events, disturbances or shocks that strongly shape the future development (Berkes et al. 2003). Based on the understanding that urban regions are social-ecological systems, these uncertainties must be incorporated into integrated approaches. The following paragraphs outline the transdisciplinary setting and research approach of plan B:altic and its application to local and regional contexts, and resilience thinking as a bridging concept for transdisciplinary research.

16.2 Transdisciplinary Research Concept of Plan B:altic

The overarching aim of the research project is to develop a common and integrated social-ecological approach to adaptation strategies, based on scientific analysis and exchange between practitioners, stakeholders and citizens. Against the background of climate change, transdisciplinary approaches are increasingly used in research projects. However, the field is still dominated by approaches focusing on one specific theme, such as flooding or water (Kirshen et al. 2008; Kundzewicz et al. 2007; Chatterjee 2010), forestry, fishery or agriculture (Peach Brown 2009; Iwasaki et al. 2009; Ogden and Innes 2008). A wide range of studies deal with adaptation in the context of development (Hardee and Mutunga. 2010; Vignola et al. 2009; Flint 2009). Within these specific themes, the majority of research in climate change adaptation has focused on policy, strategies, technologies and capacities perceived as necessary to their successful deployment (Nelson 2009). The plan B:altic project aims to contribute to practical adaptation initiatives at the local level and to develop a more comprehensive and integrated process. This approach is characterized by two distinct aspects:

- A transdisciplinary research approach working across sectors and disciplines
- An intense cooperation between researchers and practitioners that influences the research agenda (Fig. 16.1)

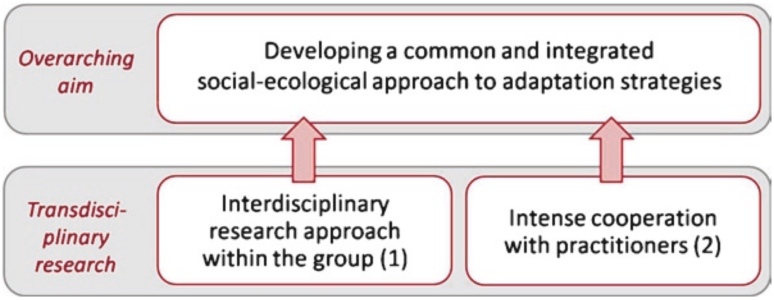

Fig. 16.1 The transdisciplinary research concept (compiled by the authors)

By integrating practical knowledge, the predominance of partial views within single disciplines can be avoided (Gunderson and Holling 2002). Transdisciplinary research provides the opportunity to combine and integrate different disciplinary perspectives, approaches and methods. Moreover, the transdisciplinary approach goes beyond science to include world-views of practitioners and to question scientific constructions. Subsequently, transdisciplinarity is understood as a research principle oriented towards practical problems rather than an academic or discipline oriented research focus (Mittelstrass 2004) in which the borders between the practical world and academic research, as well as the borders between disciplines, must be crossed (Gibbons et al. 1994). Due to the nature of this approach, paradigms and traditions of single disciplines are no longer valid, posing a new type of research problem – how to retain scientific reliability in the absence of one predominant research methodology and set of norms.

16.2.1 Transdisciplinary Research Approach Within the Research Group

Adaptation to climate change in coastal urban regions is seen as a complex, multi-level challenge which has to be analyzed as such. In practice, the different aspects cannot be considered and treated separately. Local and regional actors, especially those in political and administrative decision-making positions, have to deal with the full range of challenges while facing climate change. To reflect this and to achieve useful results for practice, our research approach includes different aspects and disciplines dealing with adaptation to climate change.

The project plan B:altic is composed of seven sub-projects and one integrated cross-sectional project. The cross-sectional dimension of the project plan B:altic consists mainly of developing a common transdisciplinary approach through integrating the different scientific perspectives and the problem-view(s) of the practitioners. The seven sub-projects cover different aspects of the topic of social-ecological adaptation to climate change. Conducted by researchers within different disciplines, the seven themes of each sub-project are as follows:

1. Climate change modeling in urban regions (geo-ecology)
2. Impacts of climate change on local and regional spatial structures and vulnerabilities (to be decided)
3. Perception and communication of climate change related risks (communication science)
4. Building resilience and ethical aspects of planning (landscape planning)
5. Governance of adaptation processes (environmental science)
6. Instruments and methods of spatial planning (spatial planning)
7. Generation and transfer of knowledge (economic geography)

Within the research group, each member remains responsible for her or his specific disciplinary sub-theme. For the cross-sectional project, however, the results of the single disciplinary sub-projects will be integrated. This presents a crucial challenge for transdisciplinary work because the various perspectives, methods and theories of each discipline must be combined with the different results. The core elements of this cooperation and integration are the bridging concept, common definitions and the 'constellation analysis.'

The bridging concept serves as a conceptional framework and analytical link for all researchers. It constitutes the common conceptual point of reference and connects the approaches and questions of the individual sub-projects. It is developed jointly by all researchers so that each researcher identifies with the contents, and the aim is for it to develop and evolve throughout the course of the project. The bridging concept mainly refers to the concept of social-ecological resilience. The group of researchers developed common definitions of crucial terms, such as climate change, adaptation and urban and regional planning, during which they acknowledged the different perspectives of each member of the group. Common definitions are fundamental for discussion and work within the group as well as for communication with practitioners.

Finally, the so-called 'constellation analysis' is the third element of the transdisciplinary cooperation, seeking to integrate contributions from social sciences, engineering and natural sciences (Schoen and Kruse 2007). The 'constellation analysis' enables analysis of the interactions between different approaches; the connections and correlations (e.g. between the sub-projects) are visualized and presented in mind-maps. This method is used at different phases of plan B:altic. In this way, different understandings and perspectives of the group are brought together. The maps serve as a starting point for workshops with practitioners.

16.2.2 An Intense Cooperation with Practitioners

Cooperation encourages the discussion and development of possible solutions and give a new impetus to local and regional adaptation measures. The intense cooperation between researchers and practitioners is a priority for the project, particularly in case studies on the urban regions of Rostock (Germany), Riga (Latvia) and Stockholm (Sweden), following a 1-year preliminary phase during which interests were elicited and working contacts established. The most intensive cooperation will take place with the city of Rostock and its surrounding region, located in the north-east of Germany. More than 420,000 people live in the region, about half of them in the city of Rostock (RPV MMR 2009). Despite the potential impacts of sea level rise and changing precipitation, no concrete adaptation actions have been implemented; plan B:altic will be the first initiative involving both the city and the region. The basis of cooperation with practitioners will be a common discussion on the problem of adaptation to climate change and an analysis of the urban region of Rostock, with more specific objectives emerging from these findings. The core elements of cooperation are three scenario planning workshops which aim at giving a new impetus for the adaptation process and potential adaptation measures. Based on different scenarios of possible, alternative future developments, the aims and visions for future development of the urban region and strategies and measures for adaptation in the Rostock region will be discussed. The scenarios will be selected together with practitioners (Neumann 2005).

In contrast, the cities of Stockholm (Sweden) and Riga (Latvia) will host a single workshop, the purpose of which is to share the experiences and challenges of the cities, rather than to initiate an intensive process. Partners will include a transnational working group consisting of members of the Baltic Sea States Sub-regional Cooperation (BSSSC) most members of which are responsible for spatial planning on the regional level. Jointly, we will conduct three workshops with the aim of defining potential common problems, discussing overarching objectives and identifying potential activity-based adaptation strategies.

16.3 Resilience Thinking As the Bridging Concept

The close and complex relationship between nature and society is at the heart of the plan B:altic approach to understanding climate change. Anthropogenic climatic changes are unintended side-effects of planned human activities, while the impacts of climate change highlight human vulnerability to - and dependence on - nature. The concept of social-ecological resilience may provide a conceptual framework that is able to give due consideration to the notion of transdisciplinarity and complexity at several levels: firstly at a general level of complex nature-society interactions, secondly with regard to the hybrid (social-ecological) nature of climate change, and thirdly, with regard to the integration of theory and practice in the fields of climate change mitigation and adaptation.

As Davidson-Hunt and Berkes (2003) state, the concept of resilience has provided a significant means of understanding the linkages between social and ecological systems. As opposed to the previously dominant equilibrium-based system models founded on the belief in a stable environment with strong self-recovery mechanisms, resilience puts emphasis on dynamic processes of change (and stability), non-linear relationships, different spatial and temporal scales, and uncertainty. Above all, it has strongly contributed to overcoming commonly accepted nature/culture, environment/society dichotomies by progressing the idea of interlinked complex social-ecological systems. In other words, social-ecological systems are 'neither humans embedded in an ecological system, nor ecosystems embedded in human systems', but a different entity altogether (Walker et al. 2006). In line with this understanding of nature-society interactions, resilience is a useful theoretical framework for studying integrated social-ecological systems.

As mentioned, urban regions on the Baltic Sea coast are particularly complex and heterogeneous social-ecological systems. The complexity of urban systems can be attributed to an enormous variety of processes, interactions and patterns in rather small areas of space, which makes such systems particularly difficult to study. Despite the involvement of seven disciplines in the research project, it can only cover a small measure of the complex features and processes within urban social-ecological systems. A careful selection of key variables relevant to analysis urban systems confronted with climate related impacts is thus needed.

Due to characteristics such as uncertainty, complexity, multi-level dynamics and occasionally conflicting interests and risk perceptions, urban adaptation to climate change requires science-practice integration. Outdated linear concepts of knowledge generation have given way to more complex, multi-level and multi-directional paradigms of knowledge generation. With its focus on transformational change and dynamic learning, the resilience framework calls for transgressive forms of knowledge. Resilience can further be considered a characteristic of complex systems and a potential guiding principle for developing adaptation strategies to climate change, not merely as an approach for understanding the dynamics of social-ecological systems.

Pohl and Hadorn (2006) propose the utilization of a 'bridging concept' aiming at a systematic integration of different disciplinary areas of knowledge and research approaches. The bridging concept should be jointly developed by all disciplines involved in the research process, and must be sufficiently accessible in the context of science-practice interactions. Given those stated requirements, the conceptual framework of social-ecological resilience appears to be particularly suitable as a bridging concept within the scope of plan B:altic, offering the conceptual means to address transdisciplinarity and to integrate knowledge among different disciplines within the research group.

However, several problems emerge from the use of social-ecological resilience as the bridging concept, particularly within science-practice interactions. The resilience concept is not a simple framework, but a mixed set of related concepts, 'a broad, multifaceted, and loosely organized cluster of concepts, each one related to some aspect of the interplay of transformation and persistence' (Carpenter and Brock 2008). As such, it does not offer an established 'theory' of transformational change in social-ecological systems. On the other hand, it is an enormously productive framework, spanning different disciplines, research traditions and methods.

The central focus of learning and self-organization in resilience thinking is of enormous importance to social-ecological systems experiencing climate change. Yet translating it from conceptual framework to practical application is particularly demanding. Building resilience in social-ecological systems usually involves elements such as learning, nurturing diversity, knowledge integration, creating opportunities for self-organization etc. (Berkes et al. 2003). However, these elements are so general in nature that most research projects usually focus on one distinct variable (e.g., social learning) of these general components. While there are already some modest attempts to make the resilience concept accessible to practitioners, these are largely conceptual exercises to understand the resilience concept, and do not offer concrete methods and strategies for building it into social-ecological systems. Nevertheless, the general components of building resilience outlined above can be used at least as a sort of guiding principles for research and practical implementation.

The focus on uncertainty and complexity, inherent to the concept of resilience, implies a rather radical change of thinking in political-administrative structures which have mostly focused on developing tangible adaptation strategies in response to specific anticipated climate change impacts. Policy makers and planners have found it difficult to move beyond tangible adaptation measures in order to facilitate more general adaptive processes. This raises the question of the ways and means to encourage building resilience in complex urban systems. The aim of plan B:altic is to use the concept of social-ecological resilience both as an analytical framework for understanding the dynamics in urban social-ecological systems in the context of climate change, and as a guiding principle for developing adaptation strategies to climate change in selected urban regions.

In this sense, the resilience concept serves as a conceptual bridge between social and ecological components, different disciplines, as well as science and practice.

The notion of a bridging concept implies continuous conceptual development on a transdisciplinary basis. Responsibility for building this bridge is by necessity mutual, relying on input from both research group and partners from the sphere of practice. The quality of this linkage is reliant on the quality of communication, not least because the scientific information of plan B:altic case studies cannot be generated without the participation of practice.

16.4 Adapting to Climate Change: Challenges of Research and Practice

Transdisciplinarity and complexity represent some of the main challenges when it comes to dealing with social-ecological systems, climate change and societal adaptation to climate variability and change. Any approach aiming to develop integrated adaptation strategies to climate change in urban regions must be able to reflect a degree of this complexity. The transdisciplinary approach adopted by plan B:altic acknowledges the complexities inherent to its research themes, and pursues a path of transdisciplinary knowledge generation and integration between science and practice. Different methods are utilized, including scenario planning approaches, science-practice-interface workshops, constellation analysis and the joint development of a conceptual bridge between different system components, disciplines, and knowledge areas.

Social-ecological resilience as a bridging concept lies at the core of our focus on addressing transdisciplinarity and complexity. However, apart from the principles of transformational change, uncertainty and complexity, its practical use as a guiding principle for developing adaptation strategies evokes the question of operationalization in several ways. The first challenge concerns the operationalization of social-ecological resilience in the research process itself and the translation of this concept into concrete methods and strategies for practical adaptation to climate change. The transdisciplinary work itself evokes certain risks and challenges, such as the potential dominant influence of certain stakeholder groups on the common research process, difficulties in the communication between science and practice, the importance of tacit or implicit norms and values of all participating actors in the process etc. Implicit norms, values and constructions and potential undesired outcomes, should resilience thinking be applied as bridging concept and guiding metaphor, should be discussed jointly and made explicit.

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Chapter 17
Governance Recommendations for Adaptation in European Urban Regions: Results from Five Case Studies and a European Expert Survey*

Torsten Grothmann

Abstract This paper develops governance recommendations for urban adaptation strategies based on case studies in urban regions of five European countries, a European expert survey on guiding principles for adaptation to climate change (including more than 250 experts from all EU countries) and literature on adaptation to climate change. The case studies show that adaptation to climate change is influenced by social factors such as education, skills, values, perceptions, interests, customs, stakeholder participation and the cooperative structures between different sectors, communities, regions and policy levels. Social factors should therefore be explicitly addressed in adaptation strategies; if not taken into account, they can become significant barriers to adaptation. To adequately address social factors, every adaptation strategy should include learning, cooperation and communication strategies, which are best formulated at the local level.

Keywords Adaptation • Adaptive capacity • Communication • Governance • Social learning

* Four case studies were carried out in the context of a study in the European Alps conducted by several European partners including Potsdam Institute for Climate Impact Research, Germany. The study was mainly funded by the European Environment Agency (EEA). The fifth case study is carried out by the German project consortium ‘nordwest2050’ including the University of Oldenburg. The project is funded by the Federal Ministry of Education and Research. The European expert survey on guiding principles for adaptation was conducted by the Potsdam Institute for Climate Impact Research as part of a project funded by the EEA.

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17.1 Introduction: Social Factors in Adaptation to Climate Change

Studies carried out since the Third Assessment Report of the IPCC in 2001 show that adaptation to climate change is influenced not only by the availability of economic and technological resources, but also by social factors such as human capital (education, skills, etc.) and management structures. There are many examples where social capital, social networks, values, perceptions, interests, customs, and traditions affect the capability of communities to adapt to risks related to climate change (Adger et al. 2007). Governance approaches to adaptation should equally consider soft factors (social) and hard factors (legal, economic and technological). If social factors are not considered, they can become significant barriers to implementing adaptation.

17.2 Five Urban Case Studies and a European Expert Survey

This chapter develops governance recommendations for urban adaptation strategies. Governance recommendations are based on empirical facts resulting from five case studies in urban regions in Europe and a European expert survey on guiding principles for adaptation to climate change. Four case studies stem from a completed research project on adaptation to climate change in the European Alps. The fifth study is part of an ongoing project on adaptation in a coastal urban region.

17.2.1 The Alpine Case Studies

As a core element of a study on vulnerability and adaptation to climate change in the European Alps, local research partners conducted six regional case studies in five different countries.[1] Four case studies were conducted in urban regions: River Lavant valley (Austria), Valais (Switzerland), South Tyrol (Italy) and Savoy (France). The main objective of the case studies was to gain concrete regional insights into vulnerability and adaptation to water resource problems. Water resources in the European Alps are sensitive to climate change because they depend on snow and glacial melt water in spring and summer as well as on snow-fall in winter.

Data collection for the case studies combined a review of existing material on each case study region, interviews with stakeholders, decision-makers and experts (up to 15 interviews per case study) and a questionnaire. The questionnaire aimed at identifying the most important barriers and drivers of adaptation to water resource problems in the various regional case studies and was filled in by the case study authors. In the questionnaire, 8 meta factors (e.g., political context) and 70 sub factors (e.g., political will) for adaptation were measured. The methods are described in more detail in Grothmann (2009).

[1] Most of the results of the case studies were published in 2009 as a report by the European Environment Agency (see EEA 2009).

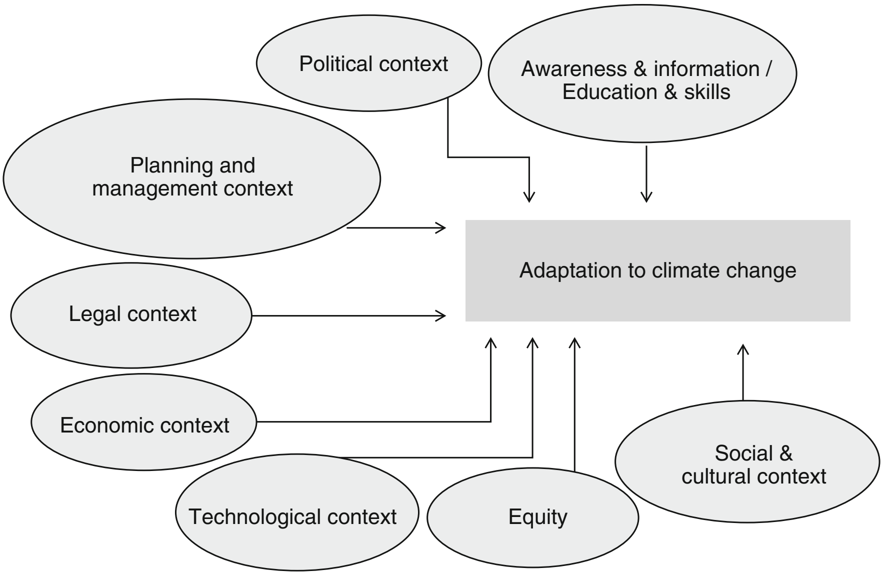

Fig. 17.1 Influential factors for adaptation to climate change

The analysis of questionnaire results revealed that the eight meta factors (see Fig. 17.1) were relevant in all regional cases. The results of the case study therefore highlight the importance of social, institutional and management factors alongside legal, economic and technological factors. Legal requirements (e.g., EU WFD), economic incentives (e.g., water prices, water markets), the availability of technological adaptation solutions (e.g., drip irrigation), and already existing water resource problems act as important triggers of adaptation to water resource issues. However, adaptation processes themselves seem to depend more on the people involved – their motivation, interests, knowledge, perceptions, competences and the availability of leaders and facilitators – and institutional and organisational factors such as the management of the adaptation process, effective stakeholder participation and the cooperative structures between different sectors, communities, regions and policy levels (Grothmann et al. 2009). Further results of the Alpine case studies are presented in Sect. 17.3.

17.2.2 The Coastal Case Study

The fifth urban case study is part of the ongoing large coastal project nordwest2050, taking place in an urban region of northwestern Germany with more than 2.3 million inhabitants.[2] The project analyses regional vulnerability to climate change impacts

[2] For more information see www.nordwest2050.de

(sea level rise, floods etc.) with regard to important economic sectors (food industry, energy production and distribution, port management and logistics). Furthermore, a long-term climate adaptation strategy is developed for the region with the time frame of 2050.

17.2.3 The European Expert Survey

In support of coordinated adaptation action, the Potsdam Institute for Climate Impact Research was involved in a project which developed a set of generic guiding principles for good practice in adaptation to climate change that shall serve as a common basis for coordinated adaptation between different sectors, actors, regions and levels of decision-making.

As a first step, about 100 different sources of literature on designing, implementing and evaluating adaptation to climate change were synthesized to develop a set of 12 guiding principles for adaptation. In the second step, the guiding principles were evaluated in an online survey by 252 adaptation experts with practical experience and/or planning responsibility in the field. Survey participants came from all European countries, from local, regional and European decision making levels, and included representatives of governments, non-governmental organisations, business organisations, and research institutes in 17 climate sensitive sectors such as civil protection, energy and health management.

The results of the survey confirm the wide applicability of the guiding principles. At all levels of decision making across all sectors, experts agreed upon the usefulness of the principles for their fields of work. More than 80% of the experts agreed that the guiding principles integrate the most important aspects of useful adaptation actions, provide useful orientation in realizing adaptation, and could be used as a basis for cooperative adaptation activities between various actors and stakeholders in Europe. For more information on the project see Prutsch et al. (2010).

17.3 Governance Recommendations

Every urban adaptation strategy should include elements of learning, cooperation and communication to address social factors. The strategies associated with these areas may partly overlap and do not represent all essential elements of an adaptation strategy. Further elements, such as management structure, should also be included, but cannot be addressed within the scope of this paper.

In reference to the meta factors that turned out to be influential in all case studies in the European Alps (see Fig. 17.1), the learning strategy mainly addresses the factors of *awareness & information/education & skills* and *planning and management context*. The cooperation strategy positively influences the same two factors and the factors of *political context*, *equity* and *social & cultural context*. The communication strategy increases the factors *awareness & information/education & skills*, *political context* and *social & cultural context*. Due to strong social networks, cities and municipalities are particularly suited to formulate social strategies, in comparison to their regional, national or international counterparts. Tackling social strategies at this level should therefore lead to higher chances of successful adaptation.

17.4 Learning Strategy

17.4.1 Learning Strategy – What For?

Learning strategies are important to successful adaptation strategies for several reasons. Vulnerability to climate change is a problem without clear solutions. Uncertainties are inherent to all projections of climate change and its impacts, but will partly be reduced by future research. Feasible adaptation strategies should be iteratively developed in a systematic governance process for improving policies and practices; an important component of this is ensuring that the outcomes of implemented policies and practices are adequately documented and learned from (Pahl-Wostl 2007). It is also important to acknowledge that many aspects of adaptation to climate change are location specific. Such specifics shape risks and opportunities, available options and barriers or drivers of adaptation. One result of the Alpine case studies illustrates the specificity of the barriers and drivers. The relevance of the 70 sub factors named in the questionnaire differed to a large extent between the regions (Grothmann et al. 2009). There seemed to be no generalizable pattern of typical barriers or drivers of adaptation to climate change; one-size-fits-all approaches are therefore inappropriate. Instead, responses should be tailored to specific regional conditions gleaned through systematic analysis of pre-conditions and implementation processes.

17.4.2 Learning – But How?

Learning components of adaptation strategies should be structured as step by step multi-decadal learning processes involving affected stakeholders and decision makers (see Gupta et al. 2010). Socio-physical conditions specific to location should be explored and monitored using trans- and interdisciplinary approaches, and should incorporate:

- risks and opportunities associated with climate change over long and short term trajectories;
- available adaptation options including also soft options such as behavioral, informational and organisational measures;

- appraisal of adaptation options based on various criteria including those of equity, cultural acceptability, legitimacy, potential side-effects or co-benefits; and
- recognition of existing barriers to, and drivers of, adaptation options.

To address the complexity of influential factors, the learning process should follow a systemic approach (Ruth 2006). As influential factors include those from environmental, economic and social areas, learning processes need to be interdisciplinary, combining knowledge from both natural and social sciences. Learning strategies should include the following elements:

- a monitoring system to improve adaptation actions, avoid maladaptation and identify new barriers and drivers;
- an evaluation system which periodically indicates progress towards meeting predefined goals while addressing direct and indirect economic and social costs and benefits;
- a training strategy for adaptation planners, increasing both climate knowledge and social competencies (moderation and negotiations skills etc.) to effectively steer the social adaptation processes;
- a knowledge management strategy documenting location-specific climate change knowledge and adaptation experiences and reviewing new scientific knowledge; and
- deliberative forms of knowledge generation bringing together the knowledge of distinct groups, such as science, business communities and non-governmental organisations.

17.5 Cooperation Strategy

17.5.1 Cooperation Strategy – What For?

Impacts associated with climate change will affect most sectors (e.g., energy, forestry, water management) as well as a variety of actor groups (government, business, NGOs, civil society) and all tiers of decision-making (local, federal, national, international). Coordinated adaptation governance is necessary in order to realize fair governance, recognize the interests of all stakeholders, avoid conflicts or unexpected problems, and to ensure synergies between adaptation activities. Cooperation between adaptation actors and stakeholders creates broad support for adaptation activities, stimulates social learning (see Sect. 17.4), empowers stakeholders to take adaptive actions themselves and reduces uncertainties surrounding goals and actions. Participatory decision making is particularly useful in reducing such uncertainties (Newig et al. 2005). The European expert survey (see Sect. 17.2.3) also reveals the importance of cooperative adaptation approaches, with 70% of experts agreeing on the guiding principle *cooperate with all relevant stakeholders*.

17.5.2 Cooperation – But How?

Adaptation should be structured as a cross-level and cross-sectoral activity that brings together actors and stakeholders including governments, businesses, environmental NGOs, scientists and citizens. Dimensions for coordination and cooperation at the city level should incorporate:

- different actors in the city, such as government, business, NGOs, citizen groups (e.g., public-private partnerships in flood protection);
- different sectors in the city affected by climate change impacts and adaptation activities (e.g., coordination of adaptation strategies in tourism and water management); and
- different adaptation-related topics, such as mitigation and general sustainability (e.g., to gain support for adaptation activities from environmental NGOs that often focus on mitigation of climate change)

The creation of city stakeholder forums, including representatives from all relevant stakeholder groups addressing the three dimensions of cooperation (actors, sectors, topics) seems to be a useful core element of a cooperation strategy. Forums should formulate stakeholder agreements on urban development priorities, acceptable risks and prioritized opportunities related to climate change. They should also find agreement on prioritized adaptation options and criteria for monitoring and evaluating adaptation activities. Experiences from Local Agenda 21 processes have shown that recommendations from stakeholder forums have some binding character for city officials.

In addition to cooperation between different stakeholders within a city, cooperation should include actors and stakeholders outside the city. Climate-related impacts often strike at scales beyond a single administration. Flood protection, for example, needs to be addressed at river basin level. All relevant stakeholders should be involved early on and throughout the adaptation process to assure fair governance, social justice and legitimacy. Particular attention should be given to including marginalized stakeholder groups (e.g., the urban poor) that are often the most vulnerable to climate change.

Finally, cooperation should occur with social and natural scientists (e.g., by a scientific advisory board). City-specific vulnerability assessments should seek the contributions of social scientists in order to more fully understand social vulnerabilities and barriers to adaptation.

17.6 Communication Strategy

17.6.1 Communication Strategy – What For?

Not all individual stakeholders that are or will be affected by climate change impacts and adaptation measures can participate in a city stakeholder forum.

A communication strategy is therefore necessary in order to easily communicate climate change to all decision makers, stakeholders and the larger public. Communication strategies should inform the public about climate change and existing adaptation activities while motivating new adaptation actions. Within many cities, sectors and organisations, information and knowledge about climate change is not sufficiently able to motivate adaptation actions.

17.6.2 Communication – But How?

Communication strategies concerning adaptation should include an element aimed at mass media. Local media is essential to bringing adaptation onto political and business agendas as well as raising awareness among the general public. Some communication experts argue that any topics not addressed in the media remain irrelevant for decision makers in policy and business.

Different cities have observed that the communication of positive, tangible (co-) benefits of adaptation is useful for motivating adaptation. For example, in Copenhagen the vision of achieving water quality that would allow for swimming in the harbor became the main argument for a comprehensive water management system. Experiences from health communication teach us to avoid catastrophic scenarios of climate change, as negative visions are often perceived as uncontrollable and result in fear and denial of the problem.

Generally, adaptation communication strategies should differentiate between different target groups that need different information and communication instruments, but also contribute to building a common knowledge base and language among stakeholders. Strategies should also include elements that allow for two-sided communication, so that stakeholders can raise additional issues or communicate disagreement with decision-makers. Internet platforms on climate change impacts and adaptation options, which have already been created in many countries, allow easy access to information and can be easily updated. These should be complemented by forms of personal communication, such as public talks or small group discussions, as these are more effective in motivating action than impersonal communication. Furthermore, personal communication builds trust and allows for mutual learning.

17.7 Concluding Remarks

The case studies presented in this chapter – consistent with many studies carried out since the 3rd Assessment Report of the Intergovernmental Panel on Climate Change in 2001 – show that adaptation to climate change is influenced by social factors. Social factors should therefore be explicitly addressed in adaptation strategies, or risk becoming significant barriers to adaptation.

To address social factors, every urban adaptation strategy should include learning, cooperation and communication elements, which local levels, due to their high degree of social interconnectedness, are well suited to deliver.

Nevertheless, many adaptation problems, such as those concerning coasts and floodplains, require adaptation action at scales that go beyond city boundaries. The project nordwest2050 is developing such regional learning, cooperation and communication strategies. The coming years will demonstrate the success of these strategies and their efficacy in addressing social factors.

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Chapter 18
Creating Resilient Cities Through Empowered, Deliberative Participation

Janette Hartz-Karp and Hans-Peter Meister

Abstract Social and physical climate change scientists agree that to effectively address climate change, we will need new 'technologies' of cooperation. Placing collaborative governance at centre stage, this paper explores how best to develop resilient cities based on best practice and innovative design. After researching best practice stakeholder collaboration, this paper analyses the common themes that characterize climate adaptation strategies, and documents the success factors typifying best practice. Based on this research and experience, it outlines the IFOK model for new governance and supporting institutional strategies. In addition, the paper argues that a more radical redesign of engagement and governance will be critical in order to achieve community resilience and joint action. It outlines how this can be achieved through collaborative governance, involving the deliberated wisdom of ordinary citizens, i.e. by instituting deliberative democracy. Examples of deliberative democratic practice across the globe are highlighted, including an innovative initiative to develop a deliberative community and collaborative governance in regional Western Australia.

Keywords Climate change adaptation • Collaborative governance • Deliberative democracy • Deliberative participation

18.1 Introduction

Local authorities are at the forefront of climate change consequences. They will bear much of the cost but also stand to benefit the most from effective climate change adaptation strategies. Scientists have proposed that the key to their effectiveness will

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depend on the extent to which they can develop new forms of cooperative governance between government, industry and civil society (McKibben 2006). However, effective, coordinated action has thus far been stymied by the complexity of climate change; it is difficult to link cause and effect in terms of time and space, and the future is often painted as uncertain or unknowable. The usual expert solutions and top-down decision-making has become inadequate, with the eternal hope for a 'silver bullet' or a 'technological fix' unlikely to materialize (Voß et al. 2006). Effective climate change action will require not only a search for best practices in stakeholder collaboration, but also more radical, systemic change in governance, where ordinary citizens have a critical role to play.

18.2 Developing Resilient Cities and New Systems of Governance

The challenges associated with adaptation to climate change and the development of resilient cities are complex and must take into consideration the following principles:

- Interdisciplinary problem solving: the problem needs to be understood beyond the sole perspectives of environmental experts to include those from engineering, the social sciences, and others;
- Interdepartmental cooperation: the involvement of numerous municipal agencies and administrations at local, state and federal levels.
- Multi-sectoral approaches: the involvement of the public, private and third sector.
- Interconnected mechanisms: linking individually-owned private residential areas with companies.

Governments have been engaging stakeholders and consulting with citizens for decades. However, many efforts led variously by government, industry and communities have tended to be narrow, one-off, short-term, one-sided, and/or motivated by self, group or local interests, with citizens generally remaining in blissful ignorance or apathy (Sarkissian et al. 2009). Citizen-led initiatives have had considerable difficulty in influencing decision-makers. To improve the status quo, best practices need to be found, criteria for success determined, and exemplary case studies disseminated.

Climate change adaptation strategies are some of the most challenging and complex areas of public policy. Analysis of global climate change best practices around the world reveal five common themes that characterize their operation:

1. Cross-cutting approach
2. Diverse actors from all sectors of society
3. Long-term perspectives

4. Communicate and operate under uncertainty
5. Understanding that local implementation is key within a global context

Within these themes, ten factors have emerged as critical to the successful implementation of climate change adaptation strategies. These success factors are based on the outcomes of a broad survey of international case studies in climate change adaptation (Meister et al. 2009) as well as experiences emerging from various projects undertaken by the Institute for Organizational Communications (IFOK):

1. Mainstreaming: the need to systematically integrate the projected consequences of climate change and necessary adaptation measures with all relevant planning and development strategies from land use planning to public health emergency plans.
2. Adaptation as a policy and practice needs to be institutionalized across different government departments and functions. Government officials need to cooperate across branches, ministries and departments. Additionally, the business community, academia and society at local, regional and national levels need to be involved.
3. Adaptation to climate change should be linked with existing strategies, structures and goals to avoid duplicating efforts.
4. All relevant stakeholders should be systematically involved in order to ensure that adaptation measures have a broad support base. This includes NPOs/NGOs, public education, industry and academia.
5. Continuity in planning and implementation processes is critical, as well as continual progress assessments of the strategies and measures employed.
6. Sound data must be gathered to document and track the specific impacts of climate change and to enable comprehensive scenario planning.
7. In order to use the climate data effectively in the policy planning process, there needs to be cooperation between academic researchers and policy-makers. Predicting climate change is a highly complex endeavor, requiring clarity in the presentation of data.
8. Scientific uncertainty associated with predictions about the exact impacts of climate change in certain sectors can make policy action difficult. Thus, policy-makers should focus their adaptation efforts on measures where effectiveness is not dependent on highly uncertain predictions. Such ‘low-risk’ measures yield positive results even if the local impacts of climate change are greater or weaker than projected.
9. Support for local communities is crucial, given that many measures require local implementation.
10. It is important to be aware of the international nature and national security dimension of the issue. Programs can and should involve various parts of government including agencies responsible for foreign relations and defense.

18.3 The IFOK Model for New Governance and Institutional Strategies

Based on years of experience working for government administrations and municipalities, IFOK has developed a model of social change that helps to lay the groundwork for designing resilient cities through participation. The IFOK Model is based on:

- *Participation*: alliances and partnerships bringing together all relevant stakeholders
- *Political support*: inclusion of political actors and mobilization of their support
- *Institutionalization*: institutionalizing measures in existing frameworks, while creating new institutional spaces
- *Drivers*: identifying drivers and initiators of change, comprised of legitimate agents able to shape the direction of the change
- *Public communication*: capturing the public attention through media and press activities

In addition, IFOK contributed to a 1999 German Bundestag study involving different scientific disciplines covering legal, economic, social and ethical arenas related to institutional sustainability. Despite different professional languages, it revealed extraordinary consensus between the disciplines, highlighting four shared strategic recommendations for institutional sustainability:

- *Reflexivity* to evaluate externalities and to assess the propriety of existing goals and directions
- *Participation* to use the wisdom of the crowds
- *Conflict settlement* to detect varying interests early on and to provide frameworks for dealing with them
- *Innovation strategies* to continuously search for improvement and to integrate new developments and changes as they arise

18.3.1 Case Study Examples of the IFOK Model

Where climate change adaptation initiatives have had the greatest success, stakeholders/decision makers have developed new ways of cooperating. These include:

Baden-Württemberg sustainability strategy, Germany, where the major social and corporate players, together with broad cooperation across multiple areas have been central to the development of a comprehensive Sustainability Strategy for the Federal State of Baden-Württemberg. Through this strategy, Baden-Württemberg hopes to become an innovation center for sustainability at national and international levels.

Sustainability strategy of the Federal State of Hesse, Germany, where a comprehensive dialogue process was instituted, based on principles of broad participation and cooperation across political and technical areas. The Sustainability Strategy, comprising strategic visions, goals and concrete actions, provides a new momentum for sustainability, and makes Hesse a model region for sustainability, energy efficiency, and renewable energy.

PLAN NYC 2030, New York City, United States, where a comprehensive environmental action plan for the City was released, creating an intergovernmental task force and the launch of a citywide strategic planning process.

18.4 A New Design for Participation: Deliberative Democracy

Best practice stakeholder engagement is a critical stepping-stone in the journey towards climate change adaptation. This paper also proposes that effective climate change adaptation will depend on increased community resilience and to achieve that will require a more radical redesign to institute collaborative governance that includes ordinary citizens. Scientists have suggested we need a new technology of cooperation to adequately address climate change (McKibben 2006). The new technology suggested here is deliberative democracy, an inclusive public discourse among citizens who judiciously deliberate, arriving at coherent viewpoints which can then influence policy development and decision-making. Like any redesign (Hammer and Stanton 1995), deliberative democracy involves addressing tacit assumptions of public participation in governance and basing action on a new set of assumptions.

Our traditional assumptions are that ordinary people are often ignorant of the issues and haven't the time, interest or ability to make well-considered decisions about complex issues. While they may be able to give input, finding solutions is what elected officials and experts are trained and paid to do. Moreover, we assume that the focus of our efforts should be on engaging those immediately impacted. Deliberative democracy, on the other hand, assumes that ordinary people have the innate intelligence to understand complex issues; that they can reach coherent, communitarian outcomes; and that decisions about issues critical to a collective future should not be left to experts alone. The practical wisdom of ordinary people (Booth 2006) is critical to untangling the threads of complexity by applying personal and community values, including local, historical and interpersonal knowledge to what is considered right or good. Deliberative democracy assumes that participants need to be representative of population demographics, and include differing viewpoints. Ways of achieving this include large-scale deliberations and random sampling. Empirically, it has been demonstrated that while participants may start out 'ignorant' in certain areas, with good facilitation they can rise to the occasion, learning rapidly in order to competently deliberate (Potapchuk et al. 2005; Fishkin 2006). Moreover, the inclusion of unaligned citizens is important to democratic legitimacy (Larsen and Gunnarsson-Östling 2008).

Governments need to be seen to be listening to 'ordinary' people and not be beholden to special interests.

Secondly, we tend to assume that self-interest or rational self-maximization will be paramount - for governments, industry, communities and individuals. Since little is expected, the engagement design is often minimalist, even tokenistic. However, if we assume the capacity for collective intelligence (Atlee 2003), then engagement design becomes critical. Ways to achieve such a design involve varied opportunities for participants to deliberate, facilitated or moderated to maximize effective discourse. Deliberation involves accessing comprehensive information, listening to and understanding different viewpoints, considering options, weighing them judiciously, and searching for common ground that represents the common good.

Thirdly, western democracies assume that elected officials should make decisions, advised by technocrats and other experts. Deliberative democrats assume that our representative democracies can be augmented by deliberative democracy, with decisions on complex issues best made through collaborative decision-making involving government, ordinary citizens and industry. Ways to achieve this are by ensuring meaningful engagement, with deliberative outputs influencing decision-making and potentially transforming not only the attitudes and behavior of participants, but those of the broader public, including public officials (Gastil 2009).

18.4.1 Case Studies in Deliberative Democracy

Deliberative democracy initiatives have defined new arenas for collaborative governance. Best practice examples across the world have shown how everyday citizens can rapidly understand complex issues, weigh the pros and cons of different options and develop a coherent voice to influence decision-making. Although most of the examples outlined below are not directly related to climate change adaptation, they provide a roadmap for how deliberative democracy could be applied. The following case studies from across the globe are situated in arenas as disparate as electoral systems, budgetary allocations, technological issues, infrastructure and future sustainability. They demonstrate that by providing opportunities for inclusive participation (of people representative of the population in terms of demographics and attitudes) to carefully deliberate, the coherent voice that emerges can then play a key role in the policy development and decision-making processes.

The British Columbia Citizens' Assembly (CA): Premier Gordon Campbell established a Citizens' Assembly of 160 randomly selected citizens, one from each electoral district, who deliberated the nature of the existing electoral system over many months, supported by experts representing different viewpoints, and were able to recommend necessary changes. The Premier committed that the system proposed by the CA, in their own wording, would be put to the people in a referendum. Although the proposed system recommended by the CA, a single transferable vote, received majority support in all electoral districts in the referendum, it did not achieve the required 60% in each district (Gastil and Levine 2005). However, this initiative did show that ordinary people can understand complex issues and achieve common ground in the interests of the broader community, and that the results of such deliberations are accorded legitimacy by the public.

Porto Alegre Participatory Budgeting: The annual budgetary allocation process is turned over to thousands of ordinary people at the local and regional levels. Each year, participants congregate in each of the 16 districts to evaluate the effectiveness of the last year's budget and determine the forthcoming budget. Delegates are elected to represent them at the broader regional level where they deliberate the components for the forthcoming budget. The city budget is then formed from these aggregated preferences, using a formula that accounts for the population and relative deprivation of each district. Approximately 10% of the population takes part in this process, supported by capacity-building exercises to ensure their constructive participation (Baiocchi 2001). This process has demonstrated how large-scale decision-making can result capacity building of ordinary citizens, while providing government greater legitimacy in its decision-making.

Consensus Conferences in Denmark: The Danish parliamentary legislation process has incorporated ordinary citizens in the development of the legislation with ethical implications. Like a citizens' jury, randomly selected citizens (10–25) deliberate topical issues for 8 days over a period of 3 months. An external advisory committee of academics, practitioners and topic experts contributes knowledge and experience and lends credibility to the process. The findings of the Consensus Conference are presented to a Parliamentary Research Committee and if accepted, are passed on to legislators (Hendricks 2005; Goodin and Dryzek 2006) enabling them to systematically reflect the values and considered preferences of ordinary people on difficult issues.

Tuscan law number 69: Legislation ensures that ordinary citizens are more effectively included in governance. Two participatory processes are highlighted in the law, relating to decisions regarding large-scale infrastructure and local policy development and decision-making. An authority allocates support, including funding, to design and carry out relevant community engagement. The authority later evaluates the process, including its impacts, in particular the extent to which the outcomes were implemented. The law itself was developed using citizen engagement (Carson and Lewanksi 2008) in order to avoid 'business as usual' community engagement that is often too little, too late. This legislation provides an excellent example of how to institutionalize best practice deliberative democracy.

Geraldton 2029 and Beyond: One of the authors is working in a long term partnership with the City of Geraldton-Greenough (a city/region of 40,000 people in remote Western Australia) to develop civic deliberation and collaborative governance regarding climate change and enhanced sustainability. The outcome is not only to develop a mutually owned vision, including short and long-term actions and strategies, but also to help the region to reinforce deliberative community and collaborative decision-making processes. A new form of collaborative governance is being pioneered through an Alliance Governance Group consisting of industry, government and NGO decision-makers and ordinary citizens with the task of overseeing the process and determining and fast-tracking priority strategies. The deliberative community is being developed through wide-ranging opportunities for public deliberation, with small-scale deliberations (carried out by roughly 40 trained volunteer Community Champions) integrated with large-scale public deliberation, and with synergies created between face-to-face deliberation, social media and online deliberation. The clear, coherent voice that has emerged from these public deliberations has already enabled decision-makers to enact more comprehensive, far-reaching climate change/sustainability plans and actions than they previously felt they had the legitimacy to attempt.

Effective adaptation to climate change requires enhanced awareness, capacity and willingness of ordinary citizens to work cooperatively with each other, governments and other experts to find solutions. Concomitantly, it will require governments to be more willing and able to engage in collaborative governance, so the challenges of climate change and the strategies to address them are jointly owned. Deliberative democracy as evidenced in the above examples provides a means to achieve this.

18.5 Conclusion

Effective climate change adaptation and resiliency will require collective action based on best practice stakeholder participatory processes and models of social change, together with a new technology of cooperation as evidenced by deliberative democracy.

Stakeholder best practice requires a broad range of considerations and actions. This includes ‘mainstreaming’ climate change adaptation measures within planning and development; institutionalizing climate change adaptation policies across government and in tandem with business, academia and society; linking and integrating such strategies with other existing relevant plans; systematically involving the broad range of stakeholders; providing continuity of planning and processes, with progress assessments; gathering sound climate change impact data; improving cooperation between academics and policy-makers to enhance predictive capacity; focusing attention on effective measures independent of scientific certainty; supporting local communities; and connecting local programs with the international dimension as well as national security.

Achieving greater resilience, however, will require new ways of cooperating. Effective climate change adaptation will require the awareness, capacity and willingness of ordinary people to find a coherent voice and act together, in tandem with government, industry and NGOs. One way to achieve this is by instituting deliberative democracy, involving inclusive/representative participation in public deliberation with the outcomes influencing policy development and decision-making.

This is not simply better form of community engagement. It involves a change in paradigm, where decision-makers understand that ordinary people, given the opportunity to carefully deliberate, can help them to make legitimate decisions which more accurately reflect local community values and preferences. Common to both models is the need to develop a sound, factual information base, innovative and collaborative ways to develop potential solutions, and parallel organizational change programs for involved administrations to establish new forms of cooperation that will foster timely responses to climate change adaptation.

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Part IV
Local Strategies and Actions in Response to Climate Change

Chapter 19
Introduction: Local Strategies and Actions in Response to Climate Change

Monika Zimmermann and Nathan Brettschneider

Adaptation to climate change should not merely be a voluntary measure that a few forward thinking and advanced cities take part in; rather, it should form part of the core responsibilities of all local governments out of concern for the future of society and the economy. While this has not yet become a reality in many cities, promising examples do exist. Some of these are presented in the following chapters in order to spell out more precisely the nature and extent of adaptation at the local level.

As we have seen, much of the discussion of adaptation is taken up with the task of describing impacts and vulnerability in order to bring the need for local action clearly and convincingly into view. The contributions here offer a further exploration of that ground, outlining specific adaptation strategies taking place within cities and regions across the globe.

While mitigation has been on the local government agenda since the mid nineties – e.g., ICLEI's Cities for Climate Protection Campaign, which preceded the efforts of many national governments – the issue of adaptation within cities has been given short shrift until recently. The early debate over local adaptation was mainly driven by mitigation experts since these were often the most informed and concerned actors within local governments. Today, the common understanding among experts is that adaptation should be treated in its own right as an integral part of city development and urban planning, not merely as an add-on to mitigation measures.

Several of the following contributors explain that local climate action plans can and *should* accommodate both mitigation and adaptations approaches, and argue that decision makers should not feel compelled to choose between either option alone. This means that local governments should not avoid reducing their mitigation efforts when considering adaptation, but instead take full advantage of the benefits shared between both approaches in order to arrive at an appropriate policy response.

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While several of the following chapters deal in an expository manner with the details of climate adaptation plans within certain national authorities and local governments, they also offer strong recommendations for overcoming the obstacles that stand in the way of the successful implementation of these plans. Of course, these obstacles can vary between contexts as a result of divergences in, say, the constitutional framework conditions, size, vulnerability, or population characteristics of different cities. Despite these differences, however, several common elements have emerged that contribute to the success of adaptation at the local level. These have been identified as the following:

- a sense of urgency, accompanied by theoretical knowledge of risk, often a result of direct experience with severe climate related events;
- data availability, which can be broken down to the local level;
- multi-level approaches and support from higher levels of government, especially state and national government;
- early planning for scaling-up or scaling-down strategies throughout levels of government;
- a pro-active tradition of city policy making;
- enterprising politicians and members of senior management;
- widespread stakeholder involvement and consultation to identify risks and needed actions;
- institutional capacity to handle the challenges involving legal responsibility, staff, and knowledge transfer;
- cooperation between all local offices and departments rather than placing adaptation responsibility solely in the hands of an environmental department/office;
- consistent planning and management approach, e.g., in urban climate plans; and
- recognizing when problems are institutional in nature and thus to be settled not only by hard measures, but soft measures as well.

While several authors concern themselves with specific sectoral approaches to adaptation – e.g., urban forestry, flood prevention systems, or coastal ecosystem protection – the real depth of the issue remains clear: addressing climate change at the local level will require a collaborative and integrated approach between stakeholders across multiple fields.

Growing awareness of the broad range of threats from climate change has inspired a new set of comprehensive and systematic approaches to adaptation based on risk and vulnerability analysis. These are often promoted to help set priorities within local government. In cases where cities have been shown to be unprepared, a lack of available information is often indicated as a reason. A related theme to emerge is the need to improve the interaction between scientists and policy makers, since without detailed knowledge that particular perils pose to cities, there would be no way to address them properly. Still, once that knowledge becomes available, determining where responsibility lies within and across levels of government is often a difficult task. This is part of what makes strategic and comprehensive adaptation planning such a challenge for local governments.

Overall, efforts to identify problems and provide impact evaluations seem to be growing – e.g., through the modeling of the spatial and temporal distribution of risk in cities. However, efficient responses to tackle the impacts of a changing climate still have to be identified in many cases, tools and guidelines are not always available, and national regulations that permit the local level to act are often not in place. Of course, we should in no way be distressed by what could be regarded as the negative findings of these studies. As will become clear, it is by understanding these shortcomings that we can come to see what the tasks of developing better resilience strategies might be.

While adaptation is largely considered to be compatible with local strategies for sustainable development, potential conflicts have been identified between the two; for instance, the assumption that denser cities are inherently more sustainable may conflict with efforts to reduce the urban heat island effect through open corridors, urban green space, and increased distances between buildings. Adaptation measures have also been shown to be controversial when, for example, public funds for maintaining coastal infrastructure are requested for the benefit of particular private interests, or when zoning restrictions for flood prevention limits building development. Indeed, many cases show the difficulty of avoiding practices that may have served communities well in the past but pose a considerable burden for the future of cities.

Taken as a whole, the following chapters are intended to help decision makers pick out what ideas should be retained, and what discarded, in their own approach to adaptation and resilience. Each provides a partial lens through which we can come to appreciate the growing centrality of cities in the definition, production, and management of climate risk.

Chapter 20
Comparative Research on the Adaptation Strategies of Ten Urban Climate Plans

Luc Vrolijks, Ashley Spatafore, and Anisha S. Mittal

Abstract Urban climate plans often focus primarily on reducing greenhouse gases. However, some plans are evolving from technical CO_2 emissions reduction strategies towards strategies that cover a broader range of issues. Adaptation or climate-proofing components are becoming a major focus of attention for climate plans. This study analyses the climate plans of ten cities and examines the adaptation requirements and strategies that each have included within their plans. It examines how each city perceives its hazard profile, and analyses what changes are to be expected under the influence of climate change. The paper also reviews each city's urban vulnerability and discusses the current and expected future vulnerability as explained in their climate plans. The interpretation of the climate risk of each city provides the analytical framework for the analysis of the adaptation strategies. The study reviews how the various components of the climate risk are being addressed. It carries out this strategic analysis across the ten cities globally, and analyses the differences and similarities between each. The paper concludes with recommendations for future urban climate plans and highlights how climate adaptation strategies can be mainstreamed.

Keywords Climate adaptation strategies • Climate proofing • City climate plan analysis • Urban vulnerability analysis • Risk appraisal

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20.1 Introduction

Many urban climate plans are shifting from a technical focus on CO_2 emission reduction strategies towards more planning oriented strategies that cover a broader range of issues. One of the hot new themes emerging within climate plans is *climate proofing* – also referred to as adaptation or climate risk reduction. This paper builds on an earlier study by Urban Progress, an urban planning and advisory company, which reviewed the climate plans of New York, Chicago, San Francisco, Seattle and Portland. That analysis concluded that the plans for each city are converging towards six 'core values of climate based planning':

1. *Carbon efficiency* – reducing CO_2 production within cities to sustainable levels
2. *Climate proofing* – equipping cities to deal with anticipated changes in the climate
3. *Made to last* – building cities to retain their quality for generations to come
4. *Green economy* – promoting city economies that are resourceful, efficient and sustainable
5. *Quality of life* – ensuring that cities provide a high quality of life for their inhabitants
6. *Nature matters* **–** a city that cares about and protects its natural environment

This paper reviews how ten city climate action plans have addressed climate proofing; it evaluates how each city appraises climate change risk and vulnerability within their plans, and what their visions and action strategies are for the future. To complete the picture, we have also looked at some of the follow-up studies and planning exercises that the cities have carried out since the publication of their climate action plans. We have broadened the analysis to compare the American cities with their European and Asian counterparts. Most selected cities are members or affiliate members of ICLEI and/or the C-40 Cities Climate Leadership Group. The climate action plans were produced between 2004 and 2010, which allowed for their development to be observed over that period. The ten cities, and their baseline data, can found in Table 20.1.

The analysis of the plans combines our initial study with conceptual approaches adopted by the United Nations (UNISDR 2008) as well as material provided by ICLEI – Local Governments for Sustainability (Snover et al. 2007; ICLEI 2009). The analysis process is given in Fig. 20.1.

20.2 Comparative Analysis

20.2.1 Changing Climate

Most of the ten city climate plans include a general description of the way in which the regional climate is expected to change. The climate change outlook is often positioned as a 'call to action' (for reducing emissions) and sometimes as a basis for adaptation planning.

Table 20.1 Ten cities

City	Population	Area (mi²)	Density (/mi²)	Annual precipitation (in.)	Days above 90°	Days below 32°	Average temperature variation (°F)
Chicago	2,853,114	227	12,569	38	18	130	16–85
Miami	424,662	55	7,721	56	63	0	60–89
New York City	8,363,710	305	27,422	50	18	78	26–84
San Francisco	808,976	47	17,212	22	3	2	46–71
Seattle	598,541	84	27,422	12	1	19	36–76
Amsterdam	762,057	64	11,907	30	3	4	33–71
London	7,556,900	659	11,467	23	1	2	36–73
Madrid	3,255,944	234	13,914	17	53	55	37–88
Seoul	10,464,051	234	44,718	53	7	92	21–85
Tokyo	13,010,279	844	15,718	58	4	3	36–87

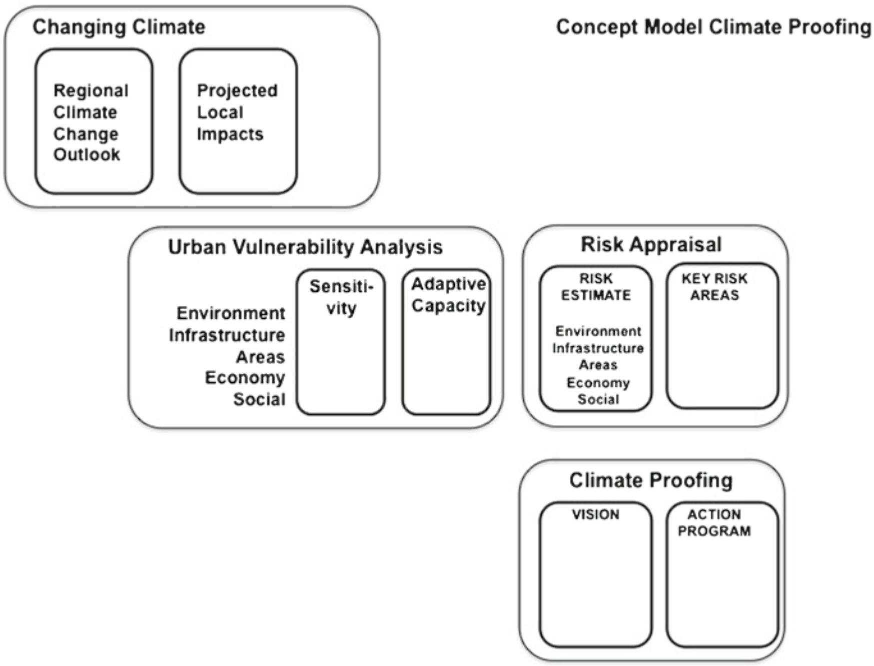

Fig. 20.1 Concept model for climate proofing analysis in urban areas

The call to action climate outlook is relatively elaborate, especially in some of the older plans. The San Francisco plan (SF DoE 2004) is a good illustration of this; its second chapter describes how climate change is expected to impact the region and quotes different scientific sources that describe likely developments caused by climate change. These include changing rainfall patterns, more extreme weather and changing sea levels. Interestingly, the San Francisco plan does not address the threats of climate change as an area of action; it only uses it as a plea for urgent attention to reduce carbon emissions. The City of Miami Climate Action Plan from 2008 follows a similar approach. It notes that Miami is ‘clearly one of the most vulnerable cities to climate change in the world,’ but it does not specify the threats to the city in great detail (City of Miami 2008).

The plans of Amsterdam (City of Amsterdam 2009), Seoul and Tokyo (Tokyo Metropolitan Government 2007) do not include a substantive analysis of the changing climate. The plan of Seoul identifies five areas of vulnerability to climate change: disease, high temperature, climate change, water shortage, and ecosystem disruption (City of Seoul 2008). Amsterdam and Tokyo describe a whole range of climate actions, but do not actually analyze or describe the climate change context of the cities themselves. It seems that the actual analysis is covered elsewhere. In the case of Amsterdam, the National Delta Commission has made a comprehensive analysis of the changing climate (Dutch Delta Commission 2008). Key features of that analysis are sea level rise and its implications for the river delta system.

The changing climate as an introduction into climate-proofing strategies is best illustrated with the Seattle Climate Action Plan (City of Seattle 2006). The city’s plan has a separate section on adaptation, which starts with a summary of the regional climate change outlook. The chapter briefly describes anticipated changes including earlier snowmelt, increased winter flooding and above average increases in temperature. The University of Washington’s Climate Impact Group prepared the overview.

In New York, Chicago and London, the regional climate change outlook in the main climate plans are limited to some key diagrams. However, the cities have since implemented additional studies, resulting in a much more elaborate climate outlook that provides a solid basis for adaptation planning. In New York, the mayor convened the New York Panel on Climate Change, which issued a Study on Climate Risk Information in February (NYC PCC 2009). The study describes a range of changes for the New York area, including milder winters, hotter summers, a slight increase in average precipitation and an increase in flooding due to extreme events.

Chicago has carried out a similar analysis, resulting in an extensive report and ‘climate change facts sheets’ (Hayhoe and Wuebbles 2007). Highlights of Chicago’s changing climate include more heat waves, faster snowmelt, more flooding and a slight decline in the water level of Lake Michigan. The Chicago study contains an interesting analysis of changes in the city’s virtual geographic position during the summer and winter, showing that the city’s future climate compares to the current climate of cities far south and east of Chicago. For London, a separate Climate Change Adaptation Strategy was prepared. This strategy follows a risk-based approach and analyses how London’s regional climate is expected to change. The conclusion is that London ‘is becoming hotter, drier and at greater risk of flooding.’ (GLA 2010)

20.2.2 Vulnerability and Risk

The analysis of vulnerability and risk is relatively incomplete in most of the climate action plans analyzed. In most cases, follow-up studies have been carried out. New York's *PlaNYC* 2030, for example, only briefly identifies what is perceived as some of the key risks for the city. That sets the agenda for follow-up actions, in particular for flood map updating and site-specific analysis (The City of New York 2007). Following this plan, the mayor conveyed the New York Panel on Climate Change, which compiled a document on climate risk information (NYC PPC 2009). This document describes the likelihood of impacts of climate change, mainly in relation to infrastructure. It does not separately address the vulnerability of ecosystems, areas or socio-economic groups. The Chicago Climate Action Plan has a similar level of detail as the PlaNYC. It sets the agenda, and focuses on what is perceived as the main risk for the city (City of Chicago 2008). In the case of Chicago, however, a Climate Impact Report was prepared before the climate plan, delivering more detail on the risks that climate change poses to the city. It analyses the expected impacts of climate change on water, health, ecosystems and infrastructure. The Chicago analysis is one of the few that addresses environmental vulnerability. The plan also addresses potential health issues affecting the population.

For Seattle and Madrid, energy supply is the core area of vulnerability. The City of Madrid Plan (2008) for the Sustainable Use of Energy and Climate Change Prevention assumes that energy security is a key risk for the city. The risk analysis itself is not included, and it is not clear if a separate vulnerability analysis has been carried out for the city's energy system. The Seattle Climate Action Plan analyzes the vulnerability of the city's hydroelectricity and water supply. The plan announces more detailed risk analysis in relation to storm water, buildings and sea level rise. The King County Climate Plan (2007) complements the work of the city. That plan is based on an appraisal of the climate change implications for the Pacific Northwest. It describes risks to public health, land use, water supply, diversity and economic risks, including insurance and agriculture.

The Miami Climate Action Plan states that Miami is 'clearly one of the most vulnerable cities to climate change in the world.' In order to outline the hazard, the plan refers to various studies, but it does not yet include an analysis of the vulnerability and risk to which the changing climate will expose the city. Instead, the plan announces that 'Miami will begin to plan for the impacts of climate change and incorporate climate change risks into long term planning.' Despite Tokyo's tradition of detailed vulnerability and risk analysis, the Tokyo plan does not describe the city's vulnerability and risk in any detail. It is possible that such analysis is carried at the national level.

The San Francisco Climate Action Plan describes the risks to which the city is exposed. It notes that shoreline infrastructure is particularly at risk. This provides the context for an approach focused on carbon reduction rather than on adaptation. Later studies include an area based flood risk analysis of the San Francisco Bay. The study was published in 2009 by the San Francisco Bay Conservation and

Development Commission and demonstrates that many of the key assets of the region, including its airports, are in climate flood zones, and that the bay's marine ecosystems are at risk from changes in the climate (SFB CDC 2009).

The overall picture is that urban vulnerability and risk are beginning to be addressed, mainly in the follow-up studies to the actual climate action plans. The focus is mostly on the expected impact of climate change on the city's infrastructure systems and supply of water and electricity. In some cases, the analysis branches out into other components of vulnerability. But the analysis still seems incomplete for most cities. In particular, economic and social components of vulnerability and risk are often lacking. Reference to the economy is indirect in most cases, covering only what is often referred to as 'the cost of inaction' (Table 20.2).

20.2.3 Climate Proofing

The ten climate plans all include some vision statement that addresses the need for climate proofing. In some cities, notably Seattle, London and Chicago, climate proofing is a strategic area that is fully integrated into the climate action plan. For most of the other cities, the initial climate plan's action programs are mainly focused on further analysis and policy design, rather than on direct action to reduce climate risks. The following summarizes some of the main climate proofing action programs that are proposed by the cities.

New York's Climate Change Action Plan was issued by the Department of Environmental Protection (NYC DEP 2008) in May. The plan focuses on addressing the potential impacts of climate change on water supply, drainage and wastewater. The plan announces further research requirements and touches upon the need to streamline government processes and tracking strategies. A key element is the establishment of a task force to analyze and prioritize the city's remaining infrastructure.

Table 20.2 Addressing vulnerability and risk

	Vulnerability and risk				
City	Environmental	Infrastructure	Areas	Economic	Social
New York	O	+	O	–	–
Chicago	+	O	–	–	O
Seattle	–	+	–	O	–
San Francisco	O	O	+	–	–
Miami	–	–	–	O	O
London	O	+	+	–	–
Amsterdam	–	–	+	–	–
Madrid	–	+	–	–	O
Tokyo	–	+	–	–	–
Seoul	O	O	–	O	–

Key: + addressed, O somewhat addressed, – not addressed

The focus of the adaptation section in the Chicago Climate Action Plan emphasizes the need to address changing weather cycles, in particular hotter summers with more frequent and intense heat waves, and the potential shift in the city's plant hardiness zone. Actions are identified in general terms, but they cover a range of solutions, e.g., heat and cooling management, air quality and storm water, 'green' design, preservation of local plants and trees, public awareness and future planning.

Seattle's Climate Action Plan includes proposals to continue to research and strategize for the changing climate. It focuses on safeguarding the city's water supply and hydroelectricity production abilities. San Francisco's immediate strategies focus on shoreline protection, safe public access, and amending policies to protect tidal marshes. Miami's climate plan only briefly touches on the subject of adaptation; despite the city's 'high risk profile,' its plan does not include specific climate proofing strategies.

Of the European plans, Amsterdam's is the briefest. Its plan has some reference to improvement of surface drainage, adaptation of infrastructure and resilience requirements for area development. Madrid's adaptation plan is the most detailed in character. It addresses a detailed list of potential impacts on a wide range of topics: Biodiversity, Water Resources, Transport, Human Health, Industry & Energy, Tourism, and Urban Planning and Construction. Madrid is the only city (in the selected plans) to provide a detailed timeline with a budget for each action. London's adaptation plan takes a risk-based approach. It includes strategies to deal with flooding, drought and overheating – with flooding as the greatest concern.

Seoul's plan focuses on two potential climate impacts: rising temperatures (heat waves and the 'tropical night phenomenon') and torrential rainfall. The city's approach is to establish a foundation for preventative adaptation before advancing smart and 'green' development. They also plan to distribute adaptation medical technology to the most vulnerable. The plan announces the establishment of a management system to adequately deal with five major climate vulnerable areas: contagious disease, temperature rise, climate-related damages, water shortage and disruption of the ecosystem. For Tokyo, no specific adaptation focused action strategies have been found. The Tokyo Climate Change Strategy and the Tokyo Metropolitan Environmental Master Plan (Tokyo Metropolitan Government 2008) do not address adaptation. In view of the city's risk of typhoons, and its low-lying position, we assume that these threats are addressed elsewhere.

20.3 Conclusions and Recommendations

20.3.1 Scope of Plans – Between Awareness and Integrated Action

The ten city climate plans examined show a wide variation in strategies for dealing with climate change. For most of the American cities, the climate plans are the first step in considering the need for adaptation. Because of this, the climate plans generally do not include comprehensive risk analysis and specific adaptation strategies. Instead, they ‘set the stage’ for further research and policy development. The scope of planning for climate change seems least developed in Miami and San Francisco. For the European and Asian cities, the situation is somewhat mixed. London has a separate adaptation plan, and Madrid is very elaborate in its strategies. Amsterdam, Seoul and Tokyo are rather brief, though the Seoul plan does define adaptation objectives. For Tokyo and Amsterdam, it seems likely that some of the key adaptation documents have not been accessed.

20.3.2 Method – Systematic Vulnerability Analysis and Risk Mapping Are Lacking

In terms of the methods that are applied, we conclude that the start and the end of the analysis are relatively well developed: most cities have a fairly good understanding of the regional climate outlook and also have an interpretation of the key risks to which the city is exposed given future changes in the climate. However, the analysis of vulnerability and risk are less pronounced. In particular, urban vulnerability is not yet systematically assessed. References to social and economic vulnerability are largely lacking. In particular, there is no clear evaluation of the vulnerability of population groups. Evidence of recent disasters, including Hurricane Katrina in New Orleans, do suggest that social vulnerability is a key aspect. A better understanding of the social component of risk would greatly enhance the strategic focus of adaptation programs. Risk mapping does not play a big role in most climate plans. Yet such maps can help communities to understand the risk to which they are exposed. A case in point is the flood evacuation plan that is included in New York’s *PlaNYC*, one of the most quoted paragraphs in the plan.

Table 20.3 Risk classification and adaptation approaches

Type of action needed	Cities	Adaptation examples
Type A – ‘To safeguard the quality of life’	Chicago Madrid New York Tokyo	Green roofs Local drainage improvements Tree planting Access to parks Transportation alternatives
Type B – ‘To deal with new and growing threats’	Madrid San Francisco Seattle Amsterdam London	Sea levees Watershed management Securing new water resources Protective measures Identify new energy sources
Type C – ‘To prepare for the worst’	Miami New York Tokyo	Scenario studies Raised housing program Water system redundancy Hurricane proof schools program Evacuation plans

20.3.3 Levels of Risk

Each of the cities is exposed to different types of risk. Table 20.3 suggests a classification of three types of risks and lists some of the adaptation approaches associated with them. Depending on the local conditions, cities may need to address one or more of these risk types. Of all the cities studied, Miami is definitely at the greatest risk. This is particularly worrying since the city's climate plan is the least developed on adaptation. On the other end of the scale, Madrid and Chicago face relatively mild climate change impacts and have elaborated plans.

20.3.4 Adaptation Strategies – Recommendations for Enhanced Climate Proofing

Overall, the plans reviewed here do not provide a comprehensive 'palette' of adaptation strategies. A greater variety of more comprehensive adaptation strategies are needed, including improved mapping, a better focus on vulnerable groups and economic sectors, the introduction of large scale coping strategies, and community supported action plans. Table 20.4 summarizes our recommendations to enhance the climate-proofing component of city climate plans.

Table 20.4 Recommendations for enhanced climate proofing

Recommendation	Description
Climate proofing research	Additional research on the projected local impacts of climate change is needed in selected cities
Enhanced focus on social and economic vulnerability	The cities should focus more attention on the social and economic components of vulnerability. When climate change materializes, these components will be very important, and adequate climate-proofing strategies require good insights into these factors
Climate risk maps	Depending on the type of threat, the next generation of climate plans could include more complete risk maps. This will not only serve the professionals, but also assist the population to understand climate risks
Climate proofing catalog	Although the actual climate-proofing actions will need to be locally adapted, cities can benefit from a Climate Proofing Catalog. Such a catalog could include best practices as well as design principles. Several resources are already available
Community supported climate proofing	Additional research is needed on how communities can best be involved in climate action and awareness. Strategies may include how celebrities can help to change behavior
Metropolitan climate strategies	The daily urban system of the cities is larger than the cities themselves; research is needed to identify effective metropolitan adaptation strategies. Such strategies would include watershed management, regional flood control, suburban climate adaptation strategies and other metropolitan level actions
Climate-fitting suburbia	More research is needed how the suburban areas can become climate proof. We suggest a combination of design studies, suburban experiments and theoretic studies to address the climate risk of suburbia

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Chapter 21
Managing Regional Climate Mitigation and Adaptation Co-benefits and Co-costs

Matthias Ruth

Abstract In many instances, climate impacts magnify the existing needs of businesses and local populations, and multiply their vulnerabilities. Strategies to reduce vulnerability are therefore increasingly placed within the broader context of social, economic and environmental policies. Within the narrower context of climate policy, co-benefits and co-costs of mitigation and adaptation have begun to inform investment and policy decisions. This paper explores mitigation and adaptation co-benefits and co-costs for a range of investment and policy cases for the coastal state of Maryland, USA.

Keywords Adaptation • Co-benefits • Decision making • Mitigation • Regional economics

21.1 Introduction

Increasingly, policy and investment decision makers are seeking solutions to curb greenhouse gas emissions and prepare for climate change impacts. While mitigation and adaptation responses are often perceived as fundamentally different, there is growing recognition that mitigation can have significant local benefits as well. This is particularly true when investments are made in proverbial 'low hanging fruit,' which may yield economic returns that outweigh costs over a short period of time. Furthermore, mitigation and adaptation can promote broader goals of social, economic and environmental resilience, which will be essential in preparing society for a wide range of future changes, including those associated with the climate.

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Past research and modeling have concentrated on the quantification of costs for specific mitigation measures and, to a lesser extent, on the cost of adaptation actions. The focus on mitigation cost was justified by the fact that benefits of mitigation efforts are frequently diffuse and hard to quantify. The discussion of adaptation strategies has long been relegated to the sidelines, largely because adaptation was perceived to simply provide local benefits without taking on global responsibilities. Similar to mitigation, the quantification of adaptation costs tended to concentrate on the up-front financial burden to those taking action.

This chapter addresses the following two interrelated questions: (1) Given the dual needs of mitigation and adaptation, what are the co-benefits and co-costs of mitigation and adaptation? (2) What is the existing context within which information on these benefits and costs can be used, at least in principle, to guide investment and policy decisions?

This chapter is structured as follows. The following section briefly highlights some of the conceptual and empirical challenges associated with the assessment of adaptation measures. Section 21.3 addresses the conceptual issues surrounding co-benefits and co-costs from climate mitigation and adaptation. Section 21.4 presents illustrations of adaptation co-benefits and co-costs from mitigation activities in the State of Maryland, USA. Section 21.5 concludes by sketching out a research and investment agenda to help reap co-benefits and help avoid co-costs.

21.2 Estimating Adaptation Cost

Policy and investment communities have begun to recognize the role of climate-induced changes at the local level – it is here were the impacts are felt first, and where adaptation needs to occur. This is also where the frontier lies in data availability and modeling that can shed light on options to improve adaptive capacity and help decision makers choose among adaptation strategies. Improving adaptive capacity means access to resources, the ability to spread risk, as well as economic, social and political institutions that properly access and evaluate information in anticipation of potential impacts while acting on the insights that that information generates (Yohe and Tol 2002; Ruth and Ibarraran 2009). Choice among adaptation strategies requires knowledge not only of the benefits compared to inaction (Ruth et al. 2007) but also of the social, health, economic and environmental co-benefits and co-costs of those actions, including implications for future greenhouse gas emissions and for changing adaptive capacity in general.

As with assessments of mitigation, the analysis of adaptation has been dominated by economic arguments. Mitigation and adaptation have been treated as substitutes despite the fact that many local climate impacts may not be avoidable through adaptation should mitigation efforts be limited (Callaway 2004). While some substitution of adaptation for mitigation is possible, it does not mean that a little less mitigation today will simply require a little more adaptation later. Rather, limited mitigation today will likely require more and continued adaptation action for the foreseeable future since limited mitigation will mean that higher atmospheric concentrations of greenhouse gases will persist over longer time horizons.

The trade-off between investment in mitigation and adaptation is typically judged on the margin; that is, by comparing the benefits and costs of a dollar invested in one strategy as opposed to another. While some adaptation options may be evaluated this way – one could think, for example, of the benefit of adding an inch to the height of a sea wall – the real value of any strategy that improves adaptive capacity will likely not be amenable to marginal analysis. The social networks required to deal with the human crises caused by flooding, the reliability of energy infrastructures to provide cooling services during heat waves, or the capability of institutions to distribute food during drought are perhaps best judged in binary terms – either they are adequate or they are not.

The following section addresses the conceptual issues surrounding the evaluation of co-benefits and co-costs and briefly evaluates the role that climate information has in helping to quantify those co-benefits and co-costs. Section 21.4 then provides illustrations of a narrower subset of issues that have not been addressed extensively in the scientific literature, namely, adaptation co-benefits of mitigation actions.

21.3 Co-benefits and Co-costs

21.3.1 The Nature and Relevance of Co-benefits and Co-costs

Despite growing recognition of the synergies between adaptation and mitigation strategies (IPCC 2007), several challenges remain for research in this area. Investigations into mitigation and adaptation are typically carried out on a case-by-case basis – say, through the assessment of an insurance policy, retreat from coastal zones, or even changes in boiler technology – precluding the development of comprehensive guidelines for the measurement and comparison of co-benefits and co-costs across cases. Complicating the analysis is a set of overlapping differences in political, spatial and temporal considerations between mitigation and adaptation projects. Ordinarily, policy decisions regarding adaptation measures are taken on an individual, local or regional level, sometimes encouraged by multinational insurance companies. In contrast, mitigation policy traditionally involves higher levels of government in setting emissions targets and approaches to reach them. Criteria for funding from major international sources for mitigation and adaptation often match this dichotomy. To complicate matters, mitigation projects often have clearly measurable outcomes with respect to avoided greenhouse gas emissions, while it is considerably more difficult to assess the value of damages avoided by adaptation.

Against this backdrop of challenges, the remainder of this paper focuses on adaptation co-benefits from mitigation actions. Traditional examples include opportunities for architecture and urban planning to help advance building standards that may reduce greenhouse gas emissions by encouraging energy efficiency. Such standards can also decrease vulnerability to extreme temperatures and weather events related to climate change. Advances in public transportation can reduce vehicle emissions, while at the same time providing an adaptation benefit by strengthening severe weather evacuation routes. These changes might have additional positive externalities, like improvements in human health from decreasing local air pollution and encouraging physical activity as a form of transportation, which in turn can result in more resilient local populations. Recognizing the conceptual and institutional constraints, this section closes with a brief discussion of data needs for the evaluation of co-benefits and co-costs.

21.3.2 Data Needs for Co-benefit and Co-cost Evaluation

Assuming it is correct that climate change multiplies existing threats to system performance, then the economic and social benefits of climate information is only one of many inputs into the investment and policy decision making process. Mitigation and adaptation strategies must also be informed by engineering information on the performance characteristics of infrastructures, demographic information on the size, composition and location of populations, geographic information on land use and land cover changes, environmental information on ecosystem health, and economic information on consumption. Since institutions are already set up to deal with some of that information, decisions on whether and how to address climate challenges tend to be made based on that information. Advances in the resolution and delivery of climate information may only have marginal economic and social benefit if those do not match the resolution and delivery of other forms of information with which these institutions operate.

21.4 Co-benefits and Co-costs of Mitigation and Adaptation: Illustrations and Limitations

The following illustrations of co-benefits and co-costs are from three different levels of 'system intervention' – a regional cap and trade system for electricity generation, an end-use sector-specific efficiency program, and a technology-focused power generation project. All three examples come from the state of Maryland and have been chosen to substantiate several points made above and to inform additional research as well as policy and investment making at the interface of climate mitigation and adaptation.

21.4.1 Regional Greenhouse Gas Initiative

Nine states in the eastern portion of the US have formed a regional greenhouse gas initiative (RGGI), which, starting in 2009, set a cap on greenhouse gas emissions for fossil fuel-fired electric generating units (RGGI 2006). Plants will need one allowance for each ton of CO_2 emitted, and they can buy or sell these allowances. The total number of allowances auctioned each year will be equal to the yearly emissions cap for the region. In total, it is estimated that RGGI will result approximately in a 35 percent reduction of CO_2 by 2020, compared to projected emissions without the cap-and-trade program (i.e., business as usual) (RGGI 2006).

By dedicating a share of Maryland's allowance revenues to efficiency, RGGI will reduce the expenditures on electricity by consumers. Total electricity bills in Maryland, depending on the year, will be between 2% and 7% lower than without RGGI. At the same time, the reductions in electricity demand resulting from greater efficiency spending will reduce Maryland in-state electricity generation and reduce electricity imports from the states that supply Maryland (Paul et al. 2010). As imports from outside the region are reduced, as households enjoy savings and as generators do not noticeably suffer losses, opportunities exist to expand adaptive capacity in the region. This could reduce susceptibility to service disruptions, particularly during peak demand periods and as severe weather events affect generation and distribution capacities. The public health outcomes of more reliable power supply in the region, particularly in urban areas among the elderly and poor, may be noticeable because extreme heat and access to air conditioning are key determinants of climate-related mortality in the region (see, e.g., Blohm et al. 2010).

21.4.2 Improving Natural Gas Use Efficiencies in Households

Natural gas is an important energy source for the residential sector in Maryland. Statewide annual residential energy consumption from natural gas is roughly equal to residential energy consumption from electricity. Considerable opportunities exist to foster cost effective natural gas efficiency improvements through the allocation of RGGI funds (Ruth et al. 2010a). From 2010 to 2025, the implementation of natural gas efficiency measures in single-family households could reduce Maryland's total residential natural gas consumption by 8–18%. The resulting energy savings and concomitant higher disposable income of households supports 4,000–5,000 jobs in Maryland and yields between $400 and $500 million in economic activity (Ruth et al. 2008).

As with the effects of RGGI on changes in adaptive capacity, the spillover of benefits and costs from efficiency improvements that affect adaptation depends on whether those savings are used by households to expand on current consumptive behaviors or whether they are diverted to make structural changes that are in tune with anticipated climate impacts. Too little is currently known about the likelihood and manifestations of changes in behaviors, land use and infrastructure investments to judge the co-benefits and co-costs of mitigation and adaptation benefits. However, since the anticipated economic impacts are small, it may be safe to assume that economic practices remain somewhat unaffected, and that as a result of local mitigation practices, the size of assets at risk increases.

21.4.3 Offshore Wind

Offshore wind power is a promising option for renewable energy generation from coal or out-of state imports into Maryland, where it is increasingly promoted to help shrink the state's carbon footprint and help diversify the state's electricity generation mix. Aside from saving three million tons of carbon emissions each year for every 1,000 MW of wind power capacity in the state, expansion of wind has the following adaptation co-benefits and co-costs:

- Greater temperature extremes increase the peak load requirements and the variability of demand for electricity. Augmenting the state's energy portfolio by investing in wind power can help the state adapt to these changes in demand patterns.
- Increased pressure on water supplies from agriculture and development are expected. Most importantly, the adequacy of water supplies during the summer is uncertain, precisely when energy demand is highest. Changes in the availability or variability of cooling water supplies makes reliance on gas, coal and nuclear power plants less attractive. Adding wind power capacity in the state of Maryland could save 1,581 million gallons of water annually for every 1,000 MW installed.
- Higher temperatures also affect the combustion efficiency of fossil-based power plants. Expansion of wind may reduce the ensuing bottleneck in peak load supply.
- Wind power generation does not emit the pollutants that fossil fuel-fired power plants do – nitrogen oxides, sulfur dioxide, mercury and other particulate matter. Therefore, meeting some portion of the state's electricity demand with wind power instead of coal, oil or gas can help decrease the state's emissions of regulated air pollutants and reduce negative health effects.
- To the extent that wind energy replaces electricity generation from out-of state coal or imports into Maryland, it can help reduce strain on the transmission system. However, integration of wind power generation into the power grid will likely require upgrades to the existing regional transmission system to maintain network reliability. In order to judge whether expansion of offshore wind generates power grid adaptation co-benefits or co-costs requires detailed knowledge of the upgrades that would have taken place anyways (Ruth et al. 2010b).
- The case has also been made that expansion of local energy sources, such as wind-generated power, positively impacts energy security of the state and the nation. Yet, offshore wind in Maryland also creates considerable conflicts by potentially limiting the effectiveness of military operations. For example, we find that the potential for diminished radar functionality exists at NASA's Wallops Flight Facility, which is used by multiple parties ranging from the Federal Aviation Administration and National Aeronautic and Space Agency, to the United States Navy. Judging the extent of those conflicts remains a challenge, especially in the light of equipment and operational changes that could mitigate them (Ruth et al. 2010b).

21.5 Managing Regional Climate Mitigation and Adaptation Co-benefits and Co-costs

Several themes emerge from the discussion above. First, mitigation and adaptation will have not only co-benefits but potentially co-costs as well. Any effort to find optimal climate change policies or investments at the regional level must be able to account for both benefit and cost spillover. Second, improvements in the spatial and temporal resolution of climate models are a necessary, though not sufficient, condition for better mitigation and adaptation. Without concomitant socioeconomic and environmental data and models that seamlessly combine with high-resolution climate data and models, information on risk, exposure to risk, and abilities to handle risk, cannot be adequately integrated to judge vulnerabilities and guide mitigation and adaptation actions. Third, even if policies and technologies that reduce emissions, promote end-use efficiency and stimulate energy diversity are available, turning over the existing stocks of infrastructures and technologies, and changing behaviors will likely take decades. By the same token, the economic, social and public health implications of mitigation and adaptation will manifest themselves over similarly long time frames. A key measure of how well mitigation strategies contribute to adaptive capacity, then, may very well be the speed at which society can adjust to the unfolding climate story, relative to the pace at which new conditions are imposed upon it. While it seems challenging to calculate – in economic and non-economic terms – the co-benefits and co-costs of action and inaction, it is even more daunting to judge the respite time of the system as a whole.

Formidable research challenges lie ahead to generate the knowledge base required to guide mitigation and adaptation actions, leverage their co-benefits, and reduce co-costs. It will require that climate information becomes an integral contributor to any form of social, economic and environmental investment and policy making, and that decision makers closely interact with the climate research community so that the necessary data and tools are developed. Much of what needs to be done within each of the relevant academic disciplines is known. The challenge will lie in putting the pieces together in the local landscape while connecting it to the larger global picture.

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Chapter 22
Interdisciplinary and Multi-institutional Approaches to Climate Change Adaptation

Virginie Moffet, Matthieu Alibert, and Caroline Larrivée

Abstract This paper focuses on the Québec government's efforts in its fight against climate change through its support of the province's local and regional municipalities, as well as the role played by Ouranos, a government-initiated research consortium whose mandate is to inform and advise decision-makers on the impacts of climate change and options for adaptation. Beyond this support, some municipalities, such as the City of Québec, have become very pro-active in reducing their greenhouse gas emissions and preparing for the inevitable impacts of climate change. This paper demonstrates how essential it has become to establish close links between different adaptation stakeholders to ensure the success of their combined efforts.

Keywords Adaptation plan • Interdisciplinary approach • Government • Guide • Municipality • Multi-institutional approach

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22.1 Introduction

The most successful adaptation actions for municipalities will be achieved through close collaboration between the various stakeholders involved in urban and regional development (IPCC 2007; America's Climate Choices 2010; Biesbroek et al. 2010; Kirshen et al. 2008; Koch et al. 2007; Ouranos 2010a, Climato and Mullan 2010). The province of Québec is investing significant efforts in climate change adaptation and is encouraging these types of collaboration through the programmes that it has developed and the projects in which it participates. This article describes the support that the government of Québec has offered municipalities, and the role played by Ouranos, a research network on regional climatology, to inform and advise decision-makers on adaptation to the impacts of climate change.

Beyond this support, some municipalities are taking proactive steps to reduce their greenhouse gas (GHG) emissions and to prepare for the inevitable impacts of climate change. This is notably the case for the Québec City urban area, which has taken steps to combat climate change since 2004 (Ville de Québec 2004, 2008, 2009). The synergy arising between these authorities, each of which have very different roles and fields of jurisdiction, has made it possible to develop core-building initiatives aimed at improving the resilience of cities in the face of climate change. This paper explains how essential it has become to develop ties between different stakeholders in order to address such a complex issue as adaptation to climate change.

22.2 Government of Québec Actions to Help Municipalities Cope with Climate Change

In 2006, the Government of Québec unveiled an important climate change action plan[1] (Gouvernement du Québec 2008) that seeks to reduce GHG emissions by 6% below 1990 levels during the period extending up to 2012. It is also meant to improve the adaptive capacity of Québec communities. These goals are in line with those advocated by the Intergovernmental Panel on Climate Change (IPCC 2007), which calls for a balanced strategy between mitigation and adaptation. It is made possible by a levy on combustibles and fuels, combined with a contribution from the Canadian federal government; funding to implement the plan amounts to $250 million CAD yearly, and totals $1.5 billion CAD over the 6 year period. For adaptation, $93 million CAD will be invested between 2006 and 2012 in the health, public safety, transportation, forestry, water and climate change research fields to better prepare Québec society for the impacts of climate change.

The fight against climate change requires the involvement of many stakeholders (IPCC 2007; New York City Panel on Climate Change 2009). Municipalities exert

[1] The action plan was updated in 2008 with the availability of additional funding.

a key influence in many fields related to the reduction of GHG emissions and climate change adaptation (Gouvernement du Québec 2008; New York City Panel on Climate Change 2009; Ouranos 2010a, b). Indeed, municipal responsibilities are varied and notably include land use planning, emergency preparedness, the maintenance and repair of public infrastructure, the protection and development of natural resources, as well as economic development. Each of these responsibilities are fields in which Québec municipalities can take action to cope with climate change.

It is in this spirit that the Government of Québec, by way of the Ministère du Développement durable, de l'Environnement et des Parcs (Department of Sustainable Development, Environment and Parks, MDDEP), has developed the Climate Municipalities Program. This program provides funding for municipalities to make an inventory of GHG emissions and draw up an action plan to reduce their emissions. Municipalities that have already done such work are offered funding to update their inventories and action plans, as well as funds to prepare a climate change adaptation plan.

22.3 A Guide to Help Municipalities

Several major cities in the province of Québec are now interested in drawing up their first climate change adaptation plan. When developing its Climate Municipality Program, the government realized that there were few, if any, references available in French to help Québec municipalities develop such a plan.

In close collaboration with Ouranos, the government developed a tool that provides guidelines for municipalities embarking upon such an initiative. The organization ensures very strong ties between research and decision-making authorities to create an environment that is conducive to a better understanding of the consequences of climate change and the development of relevant adaptation options. This experience was used to identify the most important aspects to be included in the document.

The tool takes the form of a guide (Ouranos 2010a). It explains why it is important to adapt to climate change, describes the role that municipalities can play, provides a few brief examples of impacts for municipalities, and outlines the process for developing an adaptation plan. The guide also emphasizes the importance of coordinating this initiative with other existing planning tools at the local and regional municipal levels (e.g., emergency preparedness, land use planning, and public health). This will permit the integration of considerations related to climate change in existing mechanisms and processes.

The document, validated through consultation with representatives throughout the province, is based on a review of different guides from international, national and regional public bodies, as well as non-governmental organizations (e.g., UNDP, UNEP, Least Developed Countries Expert Group, World Bank, Australian Government, New Zealand Government, ONERC, Canadian federal government, Canadian provincial governments, ICLEI USA, UKCIP). The guide is also based on an analysis of existing municipal adaptation plans (from municipalities in North America and Europe). This analysis revealed that there is practically no established procedure or approach common among cities or regions, even between those that share similar characteristics (e.g., size, population density, geographical characteristics, expected impacts). However, this examination did identify a certain number of crucial elements for the success of the initiative, such as the importance of interdisciplinary work and the need to include assessment and revision mechanisms for the plan's implementation. The steps proposed in the guide are presented in Fig. 22.1.

The guide is intended to provide a framework for the process, to explain the main steps in the preparation of a plan, and to summarize the prerequisites that will ensure the exercise is carried out successfully. Indeed, the support of senior management, the identification of persons in charge, as well as clear deliverables and a timetable, appear to be indispensable in achieving the objectives of this process and to arrive at tangible results. The tool, which is now available on the project collaborators' websites[2], can be used by the municipalities to better understand the steps that should be followed and the objectives to be achieved throughout the process.

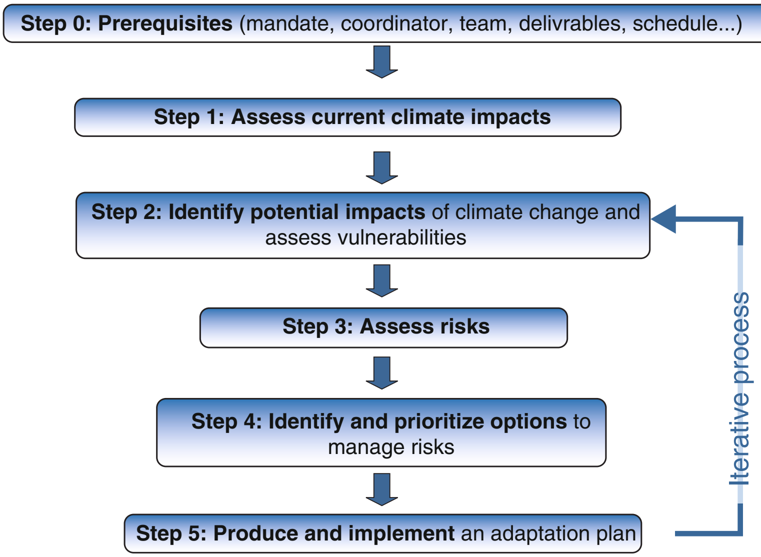

Fig. 22.1 Steps for developing a climate change adaptation plan (Ouranos 2010a)

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[2] Ouranos: http://www.ouranos.ca/fr/publications/resultats.php?q=Recherche+par+mot-cl%C3%A9%2C+titre+ou+auteur&t=8

Department of Sustainable Development, Environment and Parks (MDDEP): http://www.mddep.gouv.qc.ca/programmes/climat-municipalites/Plan-adaptation.pdf

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22.4 Adapting to Climate Change in Québec City

The province of Québec has approximately 1,115 local municipalities. Their sizes vary from just over 100 people to the densely populated city of Montréal with over 1.6 million. Québec City, the capital of the province and the second largest city (population approximately 491,000), is one of the more proactive cities of the province in regards to GHG emission reduction and adaptation to climate change.

Located along the north shore of the St. Lawrence River in the southern portion of the province, Québec City is expected to feel the effects of climate change, particularly in the form of increasingly intense weather events; i.e., snow storms, wind storms, heat waves, and rainfall (Natural Resources Canada 2010; Ouranos 2010b). Despite uncertainty over the magnitude of these anticipated climate changes, the City decided that it would be wise to prepare an adaptation plan by examining past trends and scenarios of climate change and identifying vulnerable activities and possible adaptation measures.

The City has sought to reduce the costs and harmful effects of climate change on its operations and infrastructures by taking proactive measures (Natural Resources Canada 2010). The first step involved launching the process within the Environmental Services Department of the city administration. An administration-wide plan was then devised based on the results of this small-scale experiment. It was only natural for the Environmental Service to take part in this pilot project since it has considerable knowledge of climate change and experience with the sustainable management of natural resources. The service is already responsible for the following:

- managing air, water and soil quality, as well as environmental monitoring of facilities operated by the City – in particular, wastewater treatment stations, landfills, snow depots and storm water management systems
- planting and care of urban trees and horticulture
- assessing water quality (drinking water and wastewater)

The first planning initiative established that many actions that were already provided for in other existing management plans could be considered adaptation measures since they contribute to reducing the vulnerability of systems to current weather vagaries. A consultation with some staff members made it possible to identify new and existing adaptation measures. The process unfolded in four main phases over a period of approximately 6 months.

1. *Climate change forecasts*: To prepare for the consultations, Ouranos was called upon to present climate change scenarios (for 2020, 2050 and 2080 horizons) for a series of climate indicators.
2. *Literature review*: A literature review comprising scientific journal articles and government reports was conducted to establish the likely effects of climate change on the physical infrastructures and natural areas of the city, as well as to prepare and design a methodology for drawing up the plan.

Adaptation consultation

A table was distributed to some ten members working on different activities within the Environmental Service. The project leader filled in the climate change projections section based on research findings from Ouranos. The staff members consulted then completed the impacts and adaptation strategies sections.

Exemple : Drinking water

Climate change projections	- Increasing temperatures and evapotranspiration rates ; - Absence of precipitation over long periods.
Impacts	- Fresh water supplies may be compromised during the summer because of reduced flow levels ; - Possible water shortages could lead to water restriction measures.
Proposed / existing adaptation strategies	- Set aside funding for the purchase of municipal water conservation equipment ; - Install rain water collection cisterns on selected municipal buildings ; - Develop a communication program to educate the public on how to increase the efficiency of water usage.

Fig. 22.2 Examples of summary tables resulting from the consultations within the Environmental Service Department (City of Québec)

3. *Internal consultations*: Internal consultations were held with members of the Environmental Service in order to examine proposed and existing adaptation strategies. The results were recorded in two summary tables that list the proposed measures associated with the various activities within the Service (see Fig. 22.2).
4. *Prioritizing adaptation strategies*: Meetings between the project manager and the consulted staff members were held to examine the draft version of the plan and reach consensus for its final version. Agreement was also reached concerning the level of priority that should be given to each measure. The adaptation plan resulting from the process was approved by the City's Executive Committee in April 2009. Under this plan, the Environmental Service must take into account

the effects of climate change in its activities, projects, plans and in municipal by-laws. In addition, the main findings from the consultations – including the levels of priority given, the timetable and the funding requirements – are presented in clear and concise tables. In all, no fewer than 88 adaptation measures have been targeted for the various activities that the Service is responsible for.

The majority of these measures (i.e., 54) target aquatic environments and drinking water, sectors judged to have a high level of vulnerability to climate change. Twenty-six measures are considered priority actions; 12 of these are already planned for but not implemented, and the rest are new strategies. In line with the sectors estimated to be highly vulnerable to climate change impacts, the adaptation plan assigns the highest priority to the measures dealing with water quality and availability, two issues particularly sensitive to precipitation and temperature changes. Great importance is placed on the anticipated increase in drought periods in summer, as this could cause water shortages for the municipality. The plan also accounts for an increase in sea level rise, which, when combined with reduced flow levels in the St. Lawrence River, could lead to saltwater intrusion in drinking water supply networks in several sectors of the city. Some of these questions are already part of other plans prepared by the city, but the adaptation plan provides another way to give them a priority status.

The lessons learned during this initiative have proved to be at least as important as the ensuing plan. They have also helped to confirm the approach proposed in the aforementioned guide prepared by Ouranos and the Québec Government (Ouranos 2010a). The Environmental Service has not only demonstrated that the exercise was feasible but has also succeeded in eliciting the interest of senior officials of Québec City on the question of adaptation to climate change even though the city has not experienced a climate-related event with catastrophic consequences for its population or its infrastructure that would warrant such interest.

The exercise also confirmed the importance of carrying out this approach on an interdisciplinary and multi-institutional basis since the implementation of adaptation strategies requires the participation of several services and various types of expertise. Furthermore, some adaptation measures can negatively impact other services or municipal activities. The success of such an initiative also depends on the support provided by several organizations that are not part of Québec City, such as the Climate Change Bureau of the MDDEP and Ouranos. Difficulties encountered while carrying out this project have helped to identify areas where more research or the development of tools is needed:

- The absence of a clear methodological framework, in French, applicable to a North American context and permitting an easy evaluation of the vulnerability of the Environmental Service's activities. This shortcoming was resolved in part in January 2010 with the publication of the guide, intended for Québec local and regional municipalities.
- The difficulty of finding information on specific impacts at a regional level. Continued research in the field of climate change impacts and the enhanced performance of models will make up for this deficiency in the future.

- Limiting the project to the sole responsibilities of the Environmental Service did not make it possible to act effectively on certain adaptation measures identified in the plan; i.e., those that do not fall completely under the service's responsibilities.

Following the presentation of this pilot project, which provided clear examples of adaptation strategies, Québec City's Executive Committee approved an initiative to broaden this process to all of the activities of the Québec City urban area. Québec City's mayor, Régis Labeaume, made a commitment at the launching of the Climate Municipality Program of the MDDEP to ensure that the city adopts a climate change adaptation plan. This commitment will be fulfilled thanks to the financial support provided through the Quebec Government program.

22.5 Conclusion

Adaptation to climate change is a complex, multidimensional issue that requires the participation and coordinated action of multiple stakeholders. The development of knowledge and tools in the field of regional climatology, together with the funding offered to municipalities by the government of Québec will encourage the development of adaptation plans at the local level. This initiative shows how crucial it has become to build close collaboration between researchers, different levels of government, and other stakeholders, in order to ensure the success of adaptation efforts.

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Chapter 23
Climate Adaptation Strategies: Evidence from Latin American City-Regions*

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Abstract Since cities are both a key source of greenhouse gas emissions and highly vulnerable to the consequences of climate change, many are starting to take actions to mitigate and confront the anticipated effects. Latin America and the Caribbean, the most urbanized region worldwide after North America, are no exception. This contribution studies the state of adaptation strategies of two Latin American agglomerations: São Paulo and Santiago de Chile. The article, first, characterizes the adaptation efforts of the two cases based on local climate conditions with respect to actors, priorities and approaches. Second, it derives particular implementation challenges. It shows that each of the two approaches has distinct advantages as well as constraints. Common to both approaches is the challenge of preparing local governance for the long term risks of climate change. The research is based on a review of official documents, expert interviews, literature reviews and analysis of statistical data.

Keywords Climate adaptation strategies • Climate governance • Santiago de Chile • São Paulo

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23.1 Moving Cities into Focus: The Emerging Interest in Urban Climate Adaptation

Adaptation has not, in contrast to mitigation, been a prominent issue in the climate change debate over the last two decades (Pielke 2005). Still, there is evidence that this perspective is currently and rapidly changing. In 2009 alone, the topic was discussed extensively on several occasions. Prominent examples are the Climate Change Congress in Copenhagen in March 2009 and the Urban Research Symposium on Cities and Climate Change in Marseille in June 2009. The arguments that justify this emerging interest in adaptation as a legitimate response to climate change are evident. First, mitigation actions will take long periods to have effect since the climate system tends to change very slowly. In this context, the recent International Panel on Climate Change Report (IPCC 2007: 6) states that: 'There is high agreement and much evidence that with current climate change mitigation policies and related sustainable development practices, global greenhouse gas (GHG) emissions will continue to grow over the next few decades.' Thus, in the meantime, cities and their residents have no choice other than to adapt to the impacts of climate change. Second, climate change adds to the pre-existing vulnerabilities of societies such as social inequality in access to infrastructure and resources, and social segregation (Bicknell et al. 2009; Dodmann and Satterswaite 2008). Third, there is a growing political voice for adaptation – mainly in countries and cities that are likely to be most severely affected by climate change (Pielke et al. 2007). Adaptation, then, is increasingly seen as an essential and integral part of climate policy alongside mitigation.

Adaptation has been defined in numerous ways across different disciplines (e.g., Smit et al. 2000). In its Second Assessment Report, the IPCC refers to climate change adaptation as the adjustment in structures, practices or processes, in order to respond to changing climate conditions and effects (IPCC 2001). Other definitions place the issue in a wider frame of global environmental change and societal response (Tompkins and Adger 2005). Dealing with adaptation requires an understanding of the vulnerability of societies and ecosystems, their capacity to respond, and the socio-economic costs of adapting to climate change (Klein et al. 2007).

Worldwide, cities are starting to become the focus of local adaptation action. The experience of so-called 'first movers' has been documented (see, e.g., Betsill and Bulkeley 2004, Kern and Bulkeley 2009, Bulkeley and Schroeder 2008, Bicknell et al. 2009) and shows a wide variety of approaches.

This article seeks to contribute evidence from Latin America, which has an urban population of almost 80% and is the most urbanized developing region in the world. It examines existing climate action plans for São Paulo and Santiago de Chile, and addresses two questions. First, what characterizes the governance of urban adaptation action with respect to actors, priorities and approaches? Second, what particular implementation challenges does each city-region face? To answer these questions, the article explores the connections between the existing and predicted local climate conditions in the two city-regions, the interactions between these climate changes and exposed urban functions, sectors and population. The analysis is based on a review of official documents, expert interviews, literature reviews and analysis of statistical data.

23.2 Climate Conditions, Climate Change Impacts and Adaptation Strategies: The Case of Santiago de Chile

Santiago de Chile is located in a river basin on the western flanks of the Andes and exhibits a subtropical dry climate with hot summers and winter rainfalls. The principal reference point for downscaled climate change scenarios (with projected data on possible future impacts of climate change) for the Metropolitan Region of Santiago is a study by the Comisión Nacional de Medio Ambiente (CONAMA 2006). The current climate and two scenario alternatives for 2071–2100 (A2 and B2, according to the IPCC) were modelled for the whole country with the PRECIS-model (Providing Regional Climates for Impact Studies) in which one of the 50 km wide transects represents an approximation to the Metropolitan Region of Santiago de Chile. The spatial resolution of cells (25 km^2) still generates large uncertainties and inaccuracies. The projections for the period 2070–2100 under the A2 and B2 scenarios suggest a potential 40% reduction in precipitation, compounded by reductions in glacial flows and higher temperatures of between 3°C and 4°C (in parts to 5°C) for a more pessimistic A2 scenario (CONAMA 2006).

Santiago is Chile's capital and economic centre, with a population of approximately six million – over 40% of the national population. The city contributes a significant share in terms of global GHG emissions – which suggests a need to increase its mitigation efforts – but also faces considerable adaptation challenges (CONAMA 2005, 2008). The adaptation challenge lies in three areas: water markets, equitable distribution of water, and climate change governance within spatial planning.

Already today, water supply bottlenecks are evident in Santiago de Chile. The limitations of the existing water market, its weakness to respond to the natural cycles in the basin, and the anticipated scarcity due to climate change, present a major adaptation challenge (Krellenberg and Heinrichs 2010). Ongoing urbanization processes, with an expected population increase to more than eight million people by 2030 (MINVU 2008), will displace agricultural activities in the region as the metropolitan area continues to expand into productive land. This may increase risk to areas that provide important environmental services for the watershed. As a consequence, water availability will decrease, the full amount of water based on existing rights will be difficult to extract, and new needs for water will most likely not be met. Conflicts will increase, particularly between the needs of residential areas and the demands of agricultural and mining activities. Environmental services such as the allocation of green spaces may also suffer. These fulfill several important services such as maintaining the region's ecosystems, improving the urban quality of life (particularly in the lower income municipalities of the city), reducing the heat island effect and water retention. Above all, there is the issue of broad-based demand reductions. The question remains as to how a potential 40% reduction in rain water availability will be met by a population in the metropolitan area that is 30% larger than at present.

The regional development strategy, metropolitan and local regulatory plans, and local development plans have not yet included climate change considerations explicitly, largely because of the sectoral approach to public sector management. At the national level, Chile established a Climate Commission in 1996 and, 10 years later, approved a Climate Change Strategy (CONAMA 2005). It concentrates on productive sectors, particularly mitigation and commercial opportunities related to the Clean Development Mechanisms (CDM). But the plan fails to put much weight on adaptation issues and does not explicitly consider urban centres, despite that over 80% of Chileans live in urban areas. The 2008 National Action Plan still retains a strong emphasis on the early strategy agenda of mitigation and impacts in productive sectors (CONAMA 2008). Adaptation still does not occupy a prominent place in the plan except in the form of several proposed sectoral studies to analyze vulnerability (such as agriculture or water) for the main geographical regions in the country (CONAMA 2008). Although urban change is not an explicit focus of the plan, all issues relate to urban transformations. Their incorporation into planning instruments is expected to be a primary challenge for climate change adaptation. It is yet unclear how this national and sector-oriented document can be translated into local action in the metropolitan region.

23.3 Climate Conditions, Climate Change Impacts and Adaptation Strategies: The Case of São Paulo

The Região Metropolitana de São Paulo is characterized by a humid subtropical climate with an average annual precipitation of 1,458 mm (based on monthly average 1961–1990, NCDC). The city is situated on the high basin of the rivers Tietê and Rio Pinheiros. Projected data on possible future climate changes have been calculated from different regional models (HadRM3P, Eta/CPTEC and RegCM3) that were used by the Centro de Previsão de Tempo e Estudos Climáticos of the Instituto Nacional de Pesquisas Espaciais (CPTEC/INPE) for downscaling the global IPCC scenarios. The result of downscaling is a set of maps and graphs representing expected annual and seasonal climate changes (anomalies to the long-term trends from 1961 to 1990) that cover five different regions in Brazil. The Metropolitan Area of São Paulo roughly falls in the region Sul do Brasil-Bacia do Paraná that shows model results at a scale from 1:12,000,000. Analogue to the regional models for Chile, the current climate and two alternatives for 2071–2100 (A2 and B2, according to the IPCC) were calculated based on long-term measurements (1960–1991) (Marengo et al. 2007). Predictions show for A2 and B2 scenarios an increase of temperature, reaching an annual increase up to 2–3°C in the optimistic and 3–4°C in the pessimistic scenario for the Metropolitan Area of São Paulo.

The projected changes in mean annual precipitation for both scenarios show anomalies between −10% and +10%. Remarkable are the expected decreases in precipitation in winter periods of 20–40% for both scenarios (Marengo et al. 2007).

São Paulo is populated by approximately 19 million people (United Nations 2009), which means that about every tenth Brazilian lives in the city-region of São Paulo. In 2007, the central municipality, the Munizipio São Paulo, counted about 11 million inhabitants (Município de São Paulo 2010). Like Santiago de Chile, the metropolitan region significantly contributes to green house gas emissions.

Already today, São Paulo is susceptible to flood events. This susceptibility is aggravated by a long ongoing process of land conversion from natural or agricultural land to urban uses (Município de São Paulo 2010) and the associated loss of storm water retention capacity. Another problem is water supply as the catchment of the Alto Tietê satisfies only 10% of the water demand (Edison 1996). The remaining supply originates from other distant catchments. Climate change will, according to available documents and interviews, further aggravate the water situation of the metropolitan region. An increasing water and energy demand and higher intensity and frequency of extreme events are likely to occur. Further probable effects are worsening air quality and related potential health risks (Jacobi 2001).

Different from the case of Santiago de Chile, climate action is taking place on both a national and local level. In 2007 Brazil established a Climate Committee, the Comite Interministerial sobre Mudanca do Clima (CIM) and passed legislation in 2008 to enact its climate action plan (Plano Nacional de Mudanças Climáticas [PNMC]) (CIM 2008) confronting local problems related to land use, water management, transportation, and disaster risk reduction.

The municipality of São Paulo was one of the first local governments in Latin America to establish a local climate action plan. Launched in 2009, Plano Municipal de Mudanças Climáticas (PMMC) operates independently from national activities and incorporates a range of objectives and measures that had been prioritized in earlier plans by the local ministry of the environment. The local plan strongly builds on transfer of ideas, knowledge and insight through external networks such as the ICLEI Cities Program and the C40 Large Cities Initiative. The development of the local climate action plan as a municipal legislation was led by the local Environmental Ministry (Secretaria do Verde e Meio Ambiente). The participatory process included two public discussion fora, expert panels and an internet-based opinion survey as well as the inclusion of local administrations, NGO representatives, scientists and media representatives. Transportation as the major concern in the public debate and of local political priority is one relevant field. The plan includes ambitious standards for emission reductions (30% until 2012, based on 2005 emissions). Apart from transportation, other relevant fields include energy, waste management and land use planning. Measures in these fields are part of already existing sustainable development strategies.

Measures dedicated to adaptation make particular reference to the evaluation of expected climate changes, their consequences and its expected vulnerabilities.

However, the preparation of the plan did not include a quantitative vulnerability assessment to climate related changes based on downscaled climate models. Such an initiative has more recently been launched by the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP 2009). This offers the possibility to refine local action.

23.4 Conclusions: Comparison of Cases and Implementation Challenges

Based on the analysis of local climate conditions and information on official local climate action in the two case studies, the first interest of this article was to explore the urban adaptation action with respect to actors, priorities and approaches in Santiago de Chile and São Paulo. There is evidence that the two approaches to climate action are quite distinct from each other.

In the case of Santiago de Chile, action has been guided by the National Government with projections of likely climate change and that effort to derive related vulnerability and to quantify the economic impacts. In so doing, the approach is characterized by a natural science framework that treats the natural system (climate change and related vulnerability of the system) and the social system (its potential responses) as separate entities. The main aim of the current action plan with respect to adaptation is the quantification of impacts on productive sectors (e.g., agriculture) or ecosystem services (e.g., water). The functional reference areas have been selected accordingly (agro-ecological zones, water catchments). Methods and data generation are driven by climate models that project observed historic trends in long-term future scenarios.

São Paulo's approach, on the other hand, is guided by social-political framing. While local action is driven primarily within the domain of the public sector, the key actor is the local (municipal) government. The main intention is to generate a collective response that builds on current capacities and perceptions of how best to deal with existing and prospective (environmental) risks. The geographic and functional reference areas are at a rather small scale; that is, from municipality down to neighbourhood levels. Methods and data generation are largely driven by qualitative work and empirical observations. The role of climate scenarios and related vulnerability assessments has been very limited.

The second aim of this article was concerned with the particular implementation challenges in the local agenda. Here, each of the approaches faces distinct constraints. In Santiago de Chile, the main challenge is related to the issue of downscaling the approach from the national framework to local action. Existing local plans and strategies have not yet included climate change considerations explicitly. In its current form, the sectoral national approach to climate action tends to reinforce this barrier. At the same time, it has so far met difficulties in generating local political commitment. It is yet unclear how this national and sector-oriented document can be translated into local action within the metropolitan region. It is apparent, however, that climate change adaptation will demand a coordinated response from government agencies within the context of a local/regional adaptation plan. Although the Dirección General de Aguas (DGA) manages the water market, the water planning dimension must be brought within the administration of the Regional Government as part of a strategy capable of engaging with the priorities of the national plan and the multiple public and private actors (stakeholders, the environment commission, the housing and urbanization ministry, the public works ministry, and municipal authorities).

The municipality of São Paulo faces the opposite challenge of scaling up its climate action from a single municipality to broader governance instruments at the urban-regional level, then subsequently, to the national scale. This includes, for example, the coordination of transport policies. Another challenge relates to upscaling in the temporal dimension. Since the plan in São Paulo was prepared without a longer term vulnerability assessment based on climate change predictions, it falls short in generating an understanding of projected climate change and its potential future risks. Only this type of knowledge will help move the adaptation agenda forward from a short term approach, focusing primarily on urgent needs, to one of preparedness with respect to the long term risks of climate change.

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Chapter 24
Adaptation in UK Cities: Heading in the Right Direction?

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Abstract Cities face a number of climatic and non-climatic challenges, many of which will interact to present serious risks to livelihoods, quality of life and safety within the urban environment. Cities in the UK are beginning to build stakeholder networks, assess their vulnerabilities, set their strategic direction and plan, and in some cases, implement adaptation measures. These measures are rarely motivated by climate change concerns alone. We suggest that adaptation requires an integrated approach in which infrastructure enables climate resilient lifestyles rather than merely offering temporary protection. More emphasis is needed on the social context of vulnerability and resilience. Many cities are making good progress in mainstreaming adaptation into their systems and plans. We present two caricatures of future cities and use this image to argue that it is also important for cities to consider more transformational change.

Keywords Adaptation • Cities • Mainstream • Resilience • Transformation

24.1 Introduction

Wealth, deprivation, diversity, tension: cities seem to concentrate all that is good and bad about human society. For better or worse, at some point over the last decade we became a species that lives predominantly in urban areas. Cities are the future. We therefore need to understand how we can make our cities sustainable and climate resilient.

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What does it mean to be ‘resilient’ or ‘vulnerable’ to climate change? The climate change community tends to understand vulnerability as the extent to which a city or its people are exposed or sensitive to climate hazards. Vulnerability is also determined by a system’s capacity to adapt to those hazards (following IPCC 2007). Vulnerability therefore includes the physical and social aspects that enable systems, such as cities, to anticipate and act to avoid future harm. Climate resilience can be understood, in simple terms, as the opposite of vulnerability. A system is resilient to the extent that it can absorb, adapt or learn from hazards without breaking down. Cities are therefore concentrations of vulnerability to climate change because they focus people in small areas and because they rely on complex infrastructure to function, namely, water, energy and transport systems (Dawson et al. 2009).

In this paper we report on lessons from the frontline of urban adaptation in the UK. We review current approaches and ask whether cities are heading in the right direction. We conclude that significant progress has been made to *mainstream* adaptation at the city level, but that cities need to re-think how they will operate in the future. Some cities may need to *transform* their plans in order to cope with the various climate and non-climate challenges that lie ahead.

24.2 Climate Change and Cities: Messages from the Frontline of Urban Adaptation

Cities face numerous challenges independent of climate change, many of which will become more serious as climate impacts intensify. New problems will also emerge. Examples of non-climate problems include: overcrowding, inequality, crime, urban sprawl and overwhelming demand for public services such as healthcare, education and utilities. Examples of climate related problems include: sea level rise, flash flooding caused by the impermeable city surfaces, water shortages, ‘water poverty’, heat stress, disease epidemics and disruptions to utilities and global supply chains. It is the interaction of climate and non-climate problems that should determine a city’s approach to adaptation and frame the challenge of achieving climate resilience.

What can we learn from existing approaches to adaptation by cities and urban areas? How are climate risks currently approached? To understand how cities are currently adapting to climate change, it is useful to think of adaptation as a *process*. The plethora of guidance on climate change and decision-support frameworks available to urban decision-makers and city planners (e.g., ICLEI 2007; UKCIP 2007; ESPACE 2008; Nordregio 2009) tend to be structured around a number of common stages. An example is the framework below, which identifies four main steps for strategy development and three cross-cutting issues (Ribeiro et al. 2009) (Fig. 24.1).

Using the framework of Ribeiro et al. (2009), we present lessons from the frontline of urban adaptation.

Fig. 24.1 Adaptation strategy guidance (Ribeiro et al. 2009)

24.2.1 Stage 1: Prepare the Ground – Getting Started

One of the most important observations from the frontline of adaptation is that it is being driven by different factors in different cities. The significance of this observation is that no *single* approach will work across all contexts, but rather multiple approaches must be taken in order to achieve the common goal of adaptation. This is particularly clear when considering the driving forces behind cities' adaptation processes. For example, the London Mayor's considerable political commitment to climate change has driven the development of a comprehensive adaptation strategy in that city.[1] The city of Manchester, on the other hand, provides an interesting contrast in that adaptation to date has been primarily driven by research conducted by the University of Manchester through a series of publicly funded projects, rather than directly by policy-makers. Adaptation does not have to be a formal policy objective. Nevertheless, it is important that decision makers and stakeholders within the city are committed to follow through with adaptation after research programmes are completed. This was the experience in New York and Boston, USA, where the sudden disbandment of urban research groups working on climate change left a gap in adaptation governance that took some time to fill (CAP 2007). The key lesson is that political commitment to adaptation can be an important success factor and a wide range of stakeholders need to be consulted and involved at an early stage.

[1] See http://www.london.gov.uk/climatechange/

24.2.2 Stage 2: Assess Vulnerability and Risk

Before responding to climate change risks, an important first step is to understand the nature of the problems faced. For cities and urban areas, this means thinking about how existing stresses, such as flood risk, may develop over time and interact with other challenges, such as urban re-development and housing demand.

Developing the evidence base on climate change risks is often achieved through the use of climate models to explore how climatic variables will change over time given certain assumptions about how society will evolve. Important evidence might include changes in temperature, precipitation or sea level rise for various future time slices.

In many cases, the results from climate modelling have been used in conjunction with other approaches. In London the first significant assessment of climate change impacts was undertaken in 2002 with a high-profile report entitled ‘London’s Warming’ (Clarke et al. 2002). This report identified the threats and opportunities posed by climate change and started the process of addressing the responses needed through the use of climate projections.

Recently, London has also considered the impact of past extreme weather events on service provision within the city. The Greater London Authority commissioned a report to better understand the city’s current vulnerability to extreme weather and act as a springboard for engagement with local government within London (Standley et al. 2009). The project was based on the Local Climate Impacts Profile (LCLIP) method, which is a low cost tool developed to raise awareness of the vulnerability of service providers to extreme weather (UKCIP 2009).

This information has provided a useful means of engaging stakeholders and local government on the key climate risks that London is likely to face. It has also provided a useful opportunity to explore vulnerability at a local scale within the city. The London Borough of Brent has taken this further and based its approach on the particular needs of its diverse community. Brent’s vulnerability assessment is based on more than just climate models: it sought to understand the socio-economic context of the area in question and analyse how climate impacts would affect people and systems on the ground (Benzie et al. 2009).[2]

From the authors’ experiences and observations, current efforts to understand vulnerability and risks in cities and urban areas frequently seem to underestimate or ignore the social aspects. It is predominately the physical side of climate change that is the focus for adaptation planning and response (Ribeiro et al. 2009). For example, there is less understanding of how the characteristics of different places, such as the level of urbanisation, growth rates and economic vitality

[2] See Brent Climate Change Strategy documents, particularly the Supporting Evidence, Consultation and Strategy documents, available at: http://www.brent.gov.uk/stratp.nsf/Pages/Related%20strategies%20and%20policies?OpenDocument&pid=900067

(Cutter et al. 2003) offset or exacerbate vulnerability, or how people and places may change after extreme weather events.[3]

24.2.3 Stage 3: Set Strategic Direction

Strategic direction depends to a large extent on who is involved in the leadership or governance of adaptation at the city level. It also depends on the evidence used and the process followed. The Greater London Authority (GLA) launched London's Climate Change Adaptation Strategy for the second stage of public consultation in March 2010. The GLA are making best use of stakeholders' views and knowledge to inform the Strategy.[4] The Strategy also calls for ongoing public consultation and encourages comments on ways to measure London's progress on adapting to climate change.

Other cities in the UK, such as Leeds and Newcastle,[5] have focused on developing climate change strategies that embrace mitigation and adaptation. The vision for Leeds is 'a place resilient to climate change with a strong low carbon economy and a high quality of life' (CCSG 2009). The Climate Change Partnership brings together private and public bodies (including the City council) from across the city and is responsible for working with relevant strategy groups to provide relevant and timely information on climate change as existing plans are revised.

24.2.4 Stage 4: Identify Adaptation Measures

Adaptation measures are developing across a broad spectrum, ranging from building adaptive capacity (which includes evidence building and training) to implementing measures specifically for climate change adaptation. In practice, there are few adaptations that have been undertaken solely in response to climate change risk; there are many drivers of adaptation that include general risk management, government policy initiatives and financial cost-saving behaviour (Tompkins et al. 2005). This can be illustrated through a small selection of examples of adaptation practices in London.

London is planning to invest in retrofitting measures to improve the water and energy efficiency of London homes. The project seeks to install water saving measures,

[3] There is a developing literature on the social impacts of climate change and social context to vulnerability and adaptation, see for example the Joseph Rowntree Foundation's Climate Change and Social Justice Programme (Available at: http://www.jrf.org.uk/work/workarea/climate-change-and-social-justice)

[4] Including the London Development Agency, Transport for London, London Fire and Emergency Planning Authority and Metropolitan Police Authority, as well as water suppliers, local businesses and local discussion forums.

[5] Both Leeds and Newcastle form part of the 'Core Cities' group, a network of England's major regional cities that aim to ensure that national and regional policy takes account of 'on the ground' realities, including climate change (see http://www.corecities.com/)

such as shower timers, in 1.2 million homes across London. The project team is diverse, incorporating several London stakeholders.[6] Not only will this improve water efficiency and help increase resilience to drought, it will also reduce energy bills and carbon footprints.

The London Urban Greening programme aims to reduce the risk and sensitivity of people, property and nature to the urban heat island effect and surface water flooding. The programme has numerous ancillary benefits including carbon sequestration, conservation of biodiversity, improved air quality and increased desirability of communities. The programme also has health and welfare benefits and some elements of the programme are designed to meet social objectives, such as increasing access to nature, where this is currently deficient. In particular, street tree planting has been prioritised according to the areas thought to be most in need of improvement.[7]

A further example is the 'Green Grid' that aims to provide a green infrastructure network for London and enhance the functionality of the existing green space network. Climate change adaptation is one of the objectives of the Green Grid. Specific budgets have been secured for the Street Trees and Priority Parks initiatives, but over the longer term the objective is to demonstrate that an urban greening programme should be integral to urban regeneration because of the economic benefits of green infrastructure, measured by increased productivity and sustained private sector investment.

The adaptations we are seeing in cities and urban areas are being shaped by contextual factors from a variety of scales. Adaptation is generally piecemeal and different cities are at very different stages of the generic process. This can be observed, for instance, at the European scale with the development of national adaptation strategies (Swart et al. 2009) and regional adaptation strategies (Ribeiro et al. 2009). For the purposes of this paper, the key issue in current approaches to adaptation is the ambition to *mainstream* climate change into different policy areas; the ambition is to address the risk of climate change in a way that enables 'business as usual' as much as this is possible.

24.3 Thoughts on Adaptation in Cities

From our experience we have made the following observations. As a result of the interaction between climate and non-climate problems, urban adaptation initiatives need to integrate with, and build on, existing sectoral and cross-sectoral agendas at

[6] Including the Greater London Authority, London Development Agency, London Collaborative, London Councils as well as the (national) Energy Saving Trust and Environment Agency.

[7] Criteria include: most vulnerable to the urban heat island effect under extreme summer temperatures; current street tree density; areas of multiple deprivation, air and noise quality and areas of deficiency for access to nature.

the city level. Cities already have schemes for improving social cohesion, replacing ageing water infrastructure or redeveloping post-industrial quarters, for example. Many cities have *visions* of what they want to achieve and *be* in the future. These existing initiatives need to be carried out in ways that increase resilience and explicitly consider the influence of future climate change.

However, old solutions will not always solve new problems; climate resilient cities may require innovative thinking, learning and new governance structures. The complexity of cities means no single measure can be taken to achieve climate resilience. People, as well as infrastructure, policies and places need to be climate resilient, which requires an integrated approach.

Dawson et al. (2009), from the Tyndall Centre for Climate Change Research Cities Programme, show that cities must be understood as complex systems, influenced by dynamic economic, environmental and social forces. The implication is that strategies for making cities resilient to climate change must employ a portfolio of complementary measures, such as combinations of institutional, technological and infrastructure responses: none of these can be tackled in isolation. This is key to understanding the challenge of climate resilience. It cannot be achieved through bricks and mortar alone; people must behave in resilient ways and infrastructure should enable this rather than merely offering temporary protection to vulnerable lifestyles. The people who design, build, regulate and *use* infrastructure need to share a vision of what they are trying to achieve.

24.4 Mainstreaming and Transformation

Much of the current activity in adaptation seeks to embed climate change concerns within existing processes and systems, rather than become a separate or discreet activity. The strength and appeal of this mainstreaming approach is that it usually favours smaller adjustments over dramatic ones. This has been characterised as ‘incremental’ adaptation (Nelson et al. 2007). It is reasonable to expect that many aspects of adaptation could be dealt with via this incremental approach, including autonomous (un-planned) adaptation.

However, recent evidence suggests that higher levels of global warming may occur sooner than previously thought (e.g., Fuessel 2009). What does this mean for cities planning adaptation? Minor adjustments and incremental adaptation designed to maintain business-as-usual are unlikely to protect cities from rapid climate change. In some cases, more *transformative* measures may be required (see Horrocks and Harvey 2009). To identify these requirements, assessments of vulnerability and risk must explicitly consider the worst case scenarios of climate change, for example, High++ emissions scenarios. Strategies must be challenged to see if they will cope with such changes; that is, whether a city’s vision for the future is realistic in a world of, say, +4°C climate change. In practice, cities should consider using flexible decision pathways to identify different options for different scales of challenge, including rapid and dangerous climate change challenges.

Currently, there are some good examples of radical approaches to adaptation in cities that are facing more dramatic scenarios of climate change over a longer timescale. In two reports, the Institute of Mechanical Engineers (IMechE 2009) and the Royal Institute for British Architects and the Institute of Civil Engineers (RIBA/ICE 2009) have considered the possible future of urban adaptation in the UK – especially with respect to sea level rise. The recommendations of both reports are similar: the UK must prepare for radical lifestyle changes, and must start considering the long-term viability of 'many settlements, transport routes and infrastructure sites, planning for either their defence or ordered abandonment' (IMechE 2009). The emphasis of these reports can be characterised as focusing on a more 'transformative' approach.

To identify where transformation may be required, iterative decision making processes are recommended (for example, see UKCIP 2003). These provide opportunities to re-visit objective setting, vulnerability assessments and adaptation planning as new information becomes available and as objectives evolve. In particular, our understanding of the social processes that create vulnerability to climate change, and indeed those that create resilience, will improve over time and should guide adaptation planning.

24.5 How Do Cities Need to Change?

Our analysis of current adaptation processes at the city level suggests that cities need to carefully consider their direction of travel. Below we present our thoughts on what climate resilience might look like. We created the following 'spectrum of possibility'. At one end of the spectrum we imagined a place called 'Impacts City', and at the other end, 'Resilient City' – a shining example of what could be (see Figs. 24.2 and 24.3). These are caricatures of real cities; they do not exist, but we believe they provide a useful tool for thinking about how our cities need to change.

Impacts City represents a scenario that most decision makers would wish to avoid. We asked ourselves: what features might characterise a city that has failed to anticipate the impacts of a changing climate? Impacts City is a place of winners and losers. It is entirely reliant on built infrastructure to provide services. Those who can afford it have access to a dwindling set of resources such as water, reliable electricity, shelter, green space and security. They jealously guard control of political power, which is fractious and polarised, and highly corrupt. This is because there is significant competition between the 'haves' and 'have nots'. Lower income groups, and large numbers of people immigrating to the city to escape even worse conditions in their home countries (due to global increases in famine, war and natural disasters) are in effect segregated from wealthy urban residents; flood defences only protect a few small 'islands', quickly raising the price of property behind the dyke, on top of the hill or in the urban green park. As a result, areas downstream, downhill or downtown have an even higher level of risk from flooding, urban heat islands and

Fig. 24.2 Impacts city

bad air. The wealthy rely on transport infrastructure to take them from their islands of safety (increasingly located out of town) to their places of work, causing further pollution problems and spatial segregation. The inner city becomes home to a higher concentration of immobile, vulnerable people.

The infrastructure that brings in water and energy and takes out waste is very expensive (it must be flood resilient and is newly built to replace the creaking old systems of the industrial revolution). Public finances are too stretched to subsidize such projects. Only the wealthy can afford these utilities. Even emergency relief and medical care are paid for exclusively by private insurance, which only the rich can afford. This exacerbates the gap between rich and poor, which breads resentment and social tension. Sensing this tension, the wealthy residents of Impacts City retreat deeper into their gated communities outside the city and other private spaces, building defences to keep the bitter under-classes (as well as the flood waters) out. Areas of the city become heavily controlled and policed. 'No-go' areas abound. Very little space is shared by the city's public. Welcome to Impacts City.

Resilient City is an altogether different place, where *quality of life* is enjoyed equally across different income groups and diverse communities. The city relies on natural systems and efficient, innovative, eco-infrastructure solutions for its services. From the sky, the city appears green, even though it is home to high-density

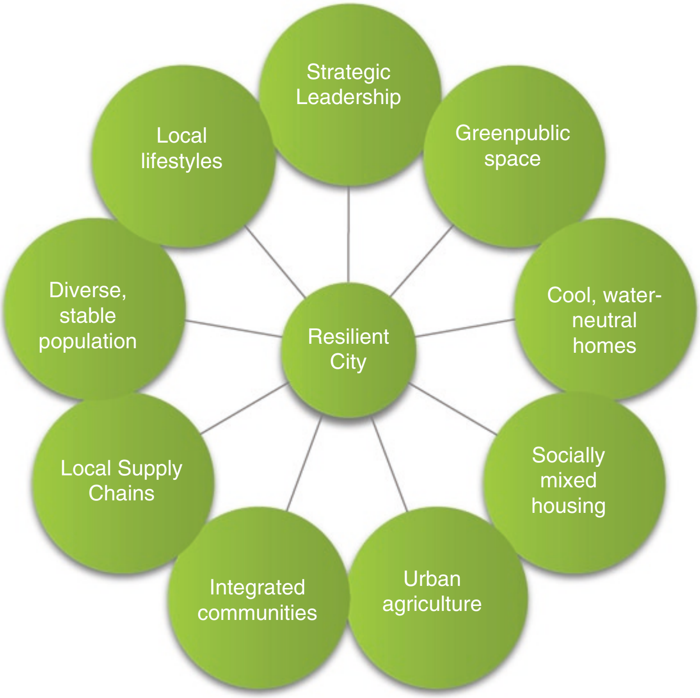

Fig. 24.3 Resilient city

living and concentrated infrastructure. Within the city as a whole, local communities operate, with services, entertainment and employment within short distances of each other, increasing the scope for zero-energy transport. Air quality is good, thanks in large part to the interconnected and expansive areas of green space, which provide free communal areas for the city's residents, as well as providing significant rainwater and flood water management and cooling services. Communities are socially mixed, well integrated and feature a variety of home designs, all of which provide passive cooling and most of which are water-neutral. Waste water and mains water facilities are provided locally and incorporated into those expansive green spaces, which also provide areas for urban agriculture, meaning that urbanites have access to fresh, local produce and reduce the risk of climate disasters affecting their supply chains overseas. The infrastructure and lifestyles in Resilient City consume little energy, the vast majority of which is locally generated from renewable sources, limiting the impact of climate events on the supply and transmission of energy. Politics within the city is consensual, open and democratic. The city's leadership is strategic and citizens recognise the benefits of investing for the long term, whilst sharing the fruits of economic activity fairly within society.

It is unlikely that the idea of either Impacts City or Resilient City accurately reflect the way in which our cities will evolve in reality. But we might recognise elements of each in the way our cities operate today, or in the decisions and trends that are at play now in cities across Europe and elsewhere. The value of these examples is to help us imagine how cities can begin to align their climate resilience and non-climate objectives in order to begin building transformative pathways into their strategies for the future.

24.6 Conclusions

We have seen that cities are beginning to adapt to climate change, demonstrating significant progress over the last few years. Our case studies highlight that adaptation is driven by a range of factors and takes many different forms. Efforts to mainstream climate considerations are making progress, but *transformation* requires us to re-think how our cities operate, how they are built and how they are lived in. Our idea of Impacts City and Resilient City helps us to imagine the wider aspects of resilience that stretch beyond direct concerns of climate into the vision of what we want cities to offer in future.

Cities need to get adaptation right, given that the success of our civilisation now depends on our ability to create and live in prosperous, diverse and sustainable urban environments. Cities such as London and Manchester have started moving in the right direction, but will they be able to meet the transformation challenge? Success will be determined by cities' foresight and imagination.

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Chapter 25
Finding the Balance: Challenges and Opportunities for Climate Change Adaptation at Different Levels of English Local Government

Nadia Manasfi and Elizabeth Greenhalgh

Abstract This paper considers some of the opportunities and challenges of adapting to climate change across different scales of local government in England. Using two-tier municipalities (county and districts) in South East England as a case study, the authors suggest three themes that have proved important in shaping adaptation at the local government level: support by senior management, regulation (mostly in the form of a performance framework), and the challenge of finding the right level of prioritisation for adaptation. The research indicates that weather and climate risks can be limited in the case of the smaller district councils, but can be of higher priority for larger county councils, which have more substantial assets and services available to them. The paper concludes by suggesting that the focus of UK public sector reform on local partnerships may present an opportunity to increase cross-organisational understanding of adaptation at the local level. At the same time, it can increase awareness of climate vulnerability within localities as a whole.

Keywords Adaptation • England • Local government • Scale

25.1 Introduction

Adaptation to climate change is now receiving more attention than ever before. This is reflected not only in the international arena, as with the negotiations of the UN Framework Convention on Climate Change (UNFCCC), but also in the policies

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Table 25.1 Some typical characteristics of county and district councils within a two-tier structure

	County	District
Geographic area	Large, ~2,600 km^2	Could be as small as 700 km^2
Population	500,000–1,500,000	~100,000
Operating costs	Can be £900 million	Can be £15 million
Physical assets	Extensive (e.g. buildings, roads, drainage)	Limited (e.g. council offices, waste depot)
Some council functions	Waste disposal, social care, emergency response, strategic planning	Environmental health, housing, local plans and planning applications

of national and local governments. This paper considers some of the opportunities and challenges of adapting to climate change at the local governance level in England, and how these play out at different scales.

Considering adaptation at the national level alone is insufficient. The impacts of global climate change will be 'felt locally and are affected by physical, social and economic factors specific to a locality' (IDeA 2009). Given the variety of location-specific geographic conditions, the nature of public infrastructure, resource accessibility and the character of local communities, local government will play a key role in designing adaptation strategies that fit an area's specific requirements (ICLEI 2007; Laukkonen et al. 2009).

This paper presents findings from research mainly conducted in 2009 with a county council and from a study of five district councils, all in southern England. These studies suggest three themes that have proved powerful in shaping the acceptance of climate change adaptation as a feature of local governance: support by senior management, regulation of local government, and finding the right level of prioritisation for adaptation.

England has a mix of two-tier and single unitary municipalities. In general, the large rural areas are governed by a two-tier system, with larger upper tier 'county' councils covering the geographical county boundaries and smaller settlements within counties represented by lower tier 'districts.' The difference in scale (e.g., size of workforce, financial budgets and scale of operation), responsibilities and functions across the two-tier structure is striking (see Table 25.1) (UKCIP 2003).

The arrangement of two-tier authorities invites questions about how these institutions, while sharing a geographic location, are affected differently by weather impacts and perceive their adaptation needs differently. It is also important to analyse whether the adaptation needs of local government institutions adequately represent the adaptation needs of the wider community or the locality as a whole.

25.2 Climate Change Adaptation in English Municipalities

In 2008, the UK introduced a new Local Government Performance Framework, which is applied to municipalities of all scales and types despite differences in their sizes, assets and responsibilities.[1] This performance framework aims to measure performance and resource use in a local area based on 198 indicators, ranging from health and education to housing and environmental sustainability (CLG 2007). One of these new indicators is National Indicator (NI) 188, ‘Preparing to Adapt to Climate Change.’ Its inclusion demonstrates the recognition by the UK government that climate change adaptation must also be considered at the local level. Evidence for adaptation should be demonstrated by meeting different levels (0–4) in a process of building organisational capacity, assessing risks and appraising options to address these risks (LRAP 2009).

25.3 Case Study Overview

The case study area is a large rural county in southern England. The county has a two-tiered local government structure (excluding the smaller town and parish council tier) with one large county council, four district councils (rural/market towns) and one city council (urban). Importantly, there are different political parties controlling tiers of local government. At the national level, the main UK political parties have reached some consensus on the need to respond to climate change. At the local level, dissent from national positions exists, adding to the challenges faced.

Both the county and district council levels studied had explored the consequences of recent weather events for their institutions using a methodology called the Local Climate Impacts Profile (LCLIP), developed by the UK Climate Impacts Programme (UKCIP 2009, 2010). These reviews revealed around 40 incidents of flooding between 1996 and 2006, several heat waves, as well as two extended dry periods. The consequences of these events differed for each local authority tier. For smaller districts, a few flood incidents had immediate and high impact but otherwise the district council was mostly unaffected. For the larger county council, the consequences of these events had complex organisational outcomes extended over a larger geographic area. For example, the hot summer in July 2006 led to the closure (and subsequent repair) of parts of the road network, the closure of some school buildings (due to concern for the health and safety of students), increased care services for the elderly, and increased workload for fire crews. For the districts,

[1] The regulation of English local governments, including the performance framework, have changed substantially since this article was researched and written.

impacts of hot weather included an increase in the numbers of people visiting open air pools, and increased calls on environmental health staff to investigate food poisoning and complaints about domestic waste odours.

25.4 Opportunities and Challenges of Adapting to Climate Change in the Case Study Area

There are some common issues arising from the organisational culture of two-tier municipalities that influence how adaptation is addressed at both tiers. However, while similar, these characteristics can play out differently in the two tiers. The common organisational features include: short time horizons underpinning policies and plan-making, the limited authority of climate change or environment officers[2] within their organisations, the resources (financial and otherwise) available to a municipality to adapt, the kinds of responses made by services to recent weather impacts (such as flooding), the capacity to take up external support (for example from UKCIP, the central government or other public agencies), and the influence of a performance management system on internal practices. We suggest that three issues are emerging strongly in shaping the way municipalities are engaging with adaptation. These are: the role played by senior management, the performance framework set by central government, and the challenge to adapt proportionately.

25.4.1 The Role of Senior Management

Regardless of tier, senior management's approach influences a municipality's capacity to incorporate adaptation within its activities. However, a significant proportion of the adaptation work that has so far taken place within both district and county councils is largely due to the work of one or two climate change officers, whose primary responsibilities lie elsewhere – mostly in energy saving and carbon reduction activities. Adaptation as an area of work is a more recent, and somewhat marginal, additional responsibility. These officers tend to have limited direct influence to bring about organisation-wide change, even though the 'adaptation task' may require just that. Their leverage is derived from persuading colleagues of the relevance of adaptation and gaining support from senior officers. According to one officer at district level, the senior decision-makers were 'supportive but not proactive' in relation to their adaptation work and direct contact between climate change officers and the councils' strategic decision-makers was usually quite limited. Furthermore, whilst government and public agencies largely accept a version of

[2] While titles can vary between each local authority, the generic title 'climate change officer' will be used here for simplicity.

climate change, political representatives can hold more sceptical opinions, which have to be accommodated (often in the form of careful self-censorship by the officers).

In a larger county council, the climate change officer requires not just the formal support of a number of senior staff but active leadership by those officers in order to achieve effective engagement across the authority. At both county and district levels there was a sense amongst climate change officers that restricted access to senior staff was, at times, a barrier to progress. However, in the smaller scale of district councils, personal contact between climate change officers and senior colleagues or elected members can allow for more informal discussion. For a large organisation such as a county council the combination of a political and senior officer grouping (Corporate Management Team, Political Cabinet, Senior Officer Teams), means there are several loci of power (although with some overlap). Thus, some consensus and shared perspective among a number of senior people is necessary in order to make decisions and enact change.

High-level arguments for the need to reduce corporate risk, protect infrastructure and investment, underpin long-term decision making, and ensure legal and financial support, are readily accepted by senior staff. However, developing the detailed practical steps needed to address climate risks and embed them in organisational processes remains a significant challenge.

The leadership shown by senior staff on climate change mitigation (energy-saving and reduction of CO_2 emissions) has not yet been mirrored by an equivalent commitment to adaptation in both tiers. However, there are particular challenges here. Adaptation is a new topic with few transferable procedural precedents. Municipalities have limited information on their own climate vulnerability and that of the locality, partly because weather related impacts are not often recorded as such. The performance of an authority is not routinely considered in relation to weather, thus weather impacts can be largely hidden from formal performance assessment. The sheer size of a larger county council makes delivering an understanding of adaptation across a large and busy institution challenging. While weather and climate risks are likely to be identified at least in part at the service or operational level (e.g., for the vulnerability of infrastructure), there is a further – and potentially more disruptive – challenge in reviewing and adapting corporate organisational processes in order to improve overall responsiveness and preparedness. For smaller districts the opportunities for senior support may appear more obvious, but can be hampered by the much smaller resource available at the district level.

25.4.2 Performance Framework

The inclusion of a performance indicator on adaptation as part of the national regulation of local government has helped local authorities incorporate adaptation into their core processes. Working through the levels of the indicator helps make explicit the organisational requirements of adaptation.

One of the main drivers of adaptation identified in interviews conducted in July 2009 was that municipalities have a duty to address NI188, even when resources are scarce. Furthermore, failing to meet their targets, including the adaptation target, could affect future funding from central government and damage the municipality's reputation. The performance indicator requires local groups of municipalities to work together and sustain progress through the levels of the indicator at a similar rate; thus, there is implicit pressure on the county council to assist the smaller district councils to ensure its own success.

The introduction of an adaptation indicator has emphasised a similar process of adaptation across all municipality types despite their differences. In terms of regulation and performance management, adaptation has been treated as an issue to be managed in intentionally generic terms, emphasising the need for flexibility in application, while in practice often masking the different needs of upper and lower tier municipalities. It is too early to tell whether the generic guidance has helped municipalities in implementing the different adaptation requirements, both in terms of building capacity or taking actions. In some instances, it has been more straightforward for districts to incorporate adaptation actions into service plans or to add weather and climate risks to risk registers simply because those plans are relatively uncomplicated. Embedding risk assessments and adaptation into the relatively small and contained administrative systems of districts can be far easier at times than embedding them into an organisation as large and complex as a county council.

25.4.3 Prioritisation

Decision making in local authorities is conducted amidst constant competing demands. A major challenge is to define a proportionate adaptation response and afford the 'right' level of attention in the context of a range of important social and economic functions delivered with finite resources. Many interviewees identified past weather impacts, mostly in the form of flooding, as a key driver for raising awareness of climate risks and spurring action to reduce the impacts. In addition to raising awareness across the council and getting buy-in from senior decision-makers, incidents such as floods can mobilise resources in terms of staff time, equipment procurement, and funding from central government to address flood risks.

The relevance of adaptation is perhaps more apparent at the scale of the county council than at the district council. Through a series of internal reviews and workshops, the county council has begun to highlight serious risks to its services and assets. These risks include damage and increased insurance and maintenance costs to buildings and infrastructure, travel disruption, implications for long-term contracts and procurement arrangements (for schools, care facilities, waste), and a delay in resuming 'normal service' following a disruptive weather event. Three key challenges for the county council are (1) moving from an identification of the relevance of adaptation to finding mechanisms for changing current practice (where necessary), (2) maintaining a programme and momentum for policy development which embeds change, and (3) accepting that adaptation decisions are integrated with other decisions and are not usually considered in isolation (Adger et al. 2005) – the challenge is to define a proportionate adaptation response. In theory, integrating adaptation within existing activity could help to ensure that 'proportionality' is achieved. However, there has to be a process by which this ambition can be assessed.

25.5 Conclusions

Our research indicates that the extent to which a municipality is exposed to weather and climate risk, and thus the extent to which it must adapt, varies according to its size, function, and location (its geophysical and social demographic characteristics). Despite these differences, however, municipalities at both district and council levels face a similar challenge of building adaptive capacity to identify and address climate risks.

County councils, with their substantial assets and services, must address priority issues revealed by the impact of recent weather events and consideration of future risk. For example, the county council studied owns hundreds of buildings and has a duty to maintain the functioning of an extensive highway network and drainage system. Weather and climate conditions can significantly impact these assets; floods could damage buildings and force residents to evacuate, heat waves and icy conditions can damage road tarmac, and sophisticated logistical arrangements for the care of a growing elderly population might be disrupted by extreme flooding or heat and threaten the capacity for the municipality to deliver its services. Unless the county council finds ways to adapt to these potential impacts, it will have to foot heavy bills to restore infrastructure and its community services.

In contrast, adaptation is not currently seen as an urgent priority for most aspects of district councils' functions and assets, as they tend to have far fewer directly owned buildings and less physical infrastructure. These features imply that the exposure and level of risk may be less than that of a county council, and a small district may rightly conclude that in terms of its own organisational interests, the risks of weather and climate are limited. Therefore, the vantage point of scale and different institutional forms give rise to differing assessments of adaptation needs according to the interests, available resources, geographic reach and optimum conditions for taking action. While both tiers in the case study area accept that flood risk and measures to cope with riverine and surface water drainage are priorities, uncertainties over responsibility for flood management has tended to complicate the policy response to flood events. The allocation of responsibilities across scales of governance and between different partner organisations to define local responses from emergency planning through infrastructure development and longer term needs presents an interesting challenge for local policy making. Furthermore, climate vulnerabilities may appear in localities in ways that do not conform to the current structures, services and partial responsibilities of local authorities. The needs of a local population may change, the local economy may alter and inequalities may arise as a result of weather and climate impacts in forms unrecognisable within current institutional arrangements. In a largely rural area served by market towns, for example, it is possible that impacts on agriculture or other local business areas as a result of weather and climate are not picked up by the district council simply because the organisation has no direct interest represented. Thus, it may also be helpful to make a distinction between an organisation's adaptation needs and an analysis of the adaptation requirement of a locality. Even though county councils have extended geographic coverage and considerable responsibilities and resources, they may not have the necessary capacity to deal with major cross-cutting issues that could emerge around impacts to health, the local economy, infrastructure and other needs. To date, adaptation discussion at the municipal level has focussed on organisational adaptation. However, since the adaptation requirements for single organisations can be different from those of a community or locality, there is growing interest in how to re-frame local government interests from a wider cross-organisational perspective, or even a location-specific perspective.

As part of the UK government's programme of public sector reform, there is ambition to move from single institutions towards partnerships in the form of multiple and interdependent relationships between municipalities and strategic partners (such as the health and police authorities) to create more responsive services in localities. Such partnership arrangements focus on improving public services within and across localities rather than the sole performance of individual organisations (ODPM 2007). A local partnership could have the potential not only to generate better cross-organisational understanding of adaptation, but also to identify potential vulnerabilities within a locality that as yet falls outside any existing institutional responsibility. In light of recent budget cuts and changes in the UK political system, it will be necessary to identify how the challenges and opportunities of adapting to climate change at the local government level in England will change, as well as what effects area-based partnerships may offer, in whatever form they take.

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Chapter 26
Local Strategies for Climate Change Adaptation: Urban Planning Criteria for Municipalities of the Basque Country, Spain

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Abstract Major efforts in the struggle against climate change have been made in the Basque Country. These include instruments such as the Basque Climate Change Office, the Basque Plan to Combat Climate Change, and the many initiatives carried out under the framework of Udalsarea 21 – Basque Network of Municipalities for Sustainability (made up of 199 municipalities and representing 98.8% of the population of the Basque Country). Moreover, specific legislation on climate change is expected to come into force in 2011. In particular, the Basque Government is developing the Climate Change Law and the Sustainable Mobility Law. Additionally, in response to the annual call for eco-innovation projects, the Basque Government is engaged in two climate change adaptation initiatives within the framework of the Udalsarea 21. Both initiatives aim at generating and piloting methodological resources to help municipal authorities establish adaptation policies. The main elements are: (1) methodological directives to draw up local adaptation strategies, and (2) preparation of specific criteria of urban adaptation to climate change to be incorporated into urban planning.

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26.1 Introduction

Natural disaster events – e.g., hurricanes, floods, tsunamis, and earthquakes – dramatically illustrate the potential vulnerability of human society to disturbances and variability (Janssen and Ostrom 2006). Scholars and practitioners from multiple disciplines have used the concepts of resilience, vulnerability, and adaptation to analyse these events with respect to both human well-being and natural ecosystems. The integrative study of these concepts is becoming increasingly important for the research community interested in the human dimensions of global environmental change.

The seriousness of climate change impacts depends on the characteristics of regions. According to scenarios developed by the IPCC (2007), highly populated coastal zones, urban areas and valleys face special challenges. Many systems and policies are not well adapted to the variability of the climate. The continuous increase in costs related to floods, draughts and storms has demonstrated the high vulnerability of our current socio-ecological systems (IPCC 2001).

The European Commission White Paper on adaptation to climate change (EC 2009) highlights the need to integrate considerations of adaptation into policies by developing actions that allow better knowledge of the impacts of climate change, assess appropriate responses, and guarantee the required funds. These actions would come as part of a regional and local adaptation agenda, which would make adjustments in decision making to reinforce resilience or reduce vulnerability to observed or forecasted changes in the climate (Adger et al. 2007).

Scientific activity is considered crucial to shift decision making in favour of adaptation. The debate over the appropriate role of science in policy making, and the development of funding mechanisms that promote its advancement, has become of greater relevance. However, the integration of the adaptation perspective in national and regional policies is fairly new (Miguel Ribeiro et al. 2009), and not homogeneous across Europe. The development of National Adaptation Plans (NAPs) encouraged by the European Commission, is having moderate success in some regions (Miguel Ribeiro et al. 2009).

The final report of the European project 'Design of guidelines for the elaboration of Regional Climate Change Adaptation Strategies' (Miguel Ribeiro et al. 2009) classified 31 initiatives in the framework of regional strategic policies to combat climate change. Although such initiatives have not yet specifically addressed adaptation issues, they have helped to introduce adaptation onto the political agenda in some way.

The adverse effects of climate change become intensified in urban areas where they are aggravated by other stresses such as population growth, changing economic activity, land-use change and urbanisation (Parry et al. 2007). Vulnerable urban communities visibly require the definition of strategies for resilience, minimized vulnerability and enhanced adaptation (Pielke et al. 2007; Adger et al. 2007).

In this regard, regional and local capacity building (through the process of adaptive governance) must include the generation of information as well as the creation of suitable legal, institutional and technical conditions required to implement adaptation measures (West and Gawith 2005). Following these recommendations, the Basque Country is making special efforts to support Basque municipalities to develop adaptation policies and strategies that include urban vulnerability assessments from an urban resilience perspective.

In early 2009, two complementary initiatives were undertaken in the framework of the annual call for eco-innovation projects organised by the Basque Government. These initiatives intend to generate methodological resources for coping with adaptation to climate change through local management and policies. The intended benefits of this process include the provision of effective joint methodological instruments that can be easily applied by municipal councils, and heightened awareness among leading stakeholders of the need to work in the field of climate change adaptation. In the following sections, these initiatives are briefly described. The last section concludes by offering further steps for the Basque leadership.

26.2 Local Initiative 1: Assessment of Vulnerability and Design of Recommendations to Adapt Basque Municipalities to Climate Change

26.2.1 Aim and Scope of the Project

Research has become necessary to assess and improve the resilience of cities. The impact of urban metabolism on the surrounding hinterlands of cities and their resident and dependant populations is widely acknowledged (Wolman 1965; Chen et al. 2008; Olazabal et al. 2009a, b; Urzelai et al. 2007; García et al. 2009; Obst-Mollering 1998). Awareness of anthropogenic changes to the earth's atmosphere has also induced measures to mitigate adverse climate effects (Arnfield 2003). Indeed, mitigation and adaptation measures must be taken into account together.

It is under this understanding that the Basque Government has funded this research initiative, which aims at defining and making accessible a reference framework for towns and cities to incorporate mitigation and adaptation measures into their urban planning practice. This framework includes a range of measures that address specific hazards alongside realistic urban planning milestones. The climate hazards analysed (sea level rise, floods and urban heat island effect) have been chosen for their relevance in the Basque Country. Urban planning procedures have also been chosen amongst those typically used in the Basque region. The results of this project will complement the Sustainable Urban Planning Handbook published by the Basque Government (2005).

26.2.2 Stages and Development

This project has been developed in for main stages:

1. Development of a methodology to assess vulnerability at the municipal level
2. Development of urban vulnerability profiles (or typologies) and generation of maps at the regional level
3. Selection of mitigation and adaptation measures
4. Development of recommendations for urban mitigation and adaptation to climate change

To successfully arrive at the expected goals, the project was developed as follows. In October 2009, a 50 page document was written in order to define the concepts of mitigation and adaptation to climate change. Several theoretical strategies to implement both concepts were discussed and the synergies between them were actively considered. The concept of vulnerability as a result of the analysis of the exposure, sensitivity and adaptive capacity of a given urban realm was detailed. Additionally, suggestions to measure and simplify the concept were provided so that they could be applied to any location. Best practices in America and Europe were studied in order to transfer any lessons learned. The principles of the Basque urban planning system were introduced in a separate chapter. Finally, some general directives were presented as a basic start-up in the fields of local ecosystem adaptation, risk management, comfort within both built and open spaces, impacts on infrastructure, and synergies between planning instruments. A methodology for assessing the vulnerability of cities to climate change was also developed. The above mentioned factors of vulnerability were translated into indicators and variables. Urban data were deployed, standardized and operated for each of the 251 municipalities of the Basque Country. Results of statistical and empirical clustering were advanced as a first attempt to validate the proposed methodology, though the results of the clustering were not as good as expected. Nevertheless, interesting conclusions were reached about the relation between the accessibility of data and its precision: as uncertainty increases, accessibility declines. A 30 page paper was presented in January 2010 explaining each municipality's characteristics and the learning process they underwent.

During February 2010, another internal research project was carried out to differentiate municipalities exposed to the urban heat island effect from those exposed to river floods or to sea level rise. More than half of the municipalities of the Basque Country were found to be affected by at least one of these exposures. For these municipalities, various social and comfort indicators were studied. These findings supported a new classification for the Basque municipalities. A methodology to construct recommendation sets for this classification was then suggested.

Finally, in April 2010, a closing document containing more than 50 practical recommendations for urban climate mitigation and adaptation was presented for urban planners and managers. It contained suggestions for the use of indicators and the results of the previous documents. The Basque planning legal framework and its instruments were also presented in depth. These were analysed in connection with the 50 recommendations in order to clarify when and where these can be better implemented. An extensive bibliography was also annexed so that further research and implementation can be pursued by pioneering municipalities.

As a follow up to the project, two validation workshops were carried out in December 2009 that discussed the methodology of vulnerability assessment for urban climates and the specific needs of each municipality. A second workshop in April 2010 focused on the feasibility of the proposed recommendations. Twenty participants were welcomed from the Basque municipalities and territorial planning institutions. Town mayors, urban planners, municipal architects, city environmental managers and key sectorial experts attended participatory meetings.

26.2.3 First Results and Expected Impacts

At the urban level in the Basque Country, many climate-related impacts are relevant. Although erosion and land slides have significant impact, the key hazards that have been considered in this study are the following:

1. *River flooding due to extreme rain events*: Given the small size of the Basque river basins, heavy rains can produce short-term, high speed avenues of water that carry away large quantities of detritus from the hills. Coupled with the fact that several large towns are placed along estuaries and that urban developments have not respected meanders and alluvial areas, these hazards could affect more than half of the municipalities – 150 out of 251 (see Fig. 26.1).
2. *Slow but continuous sea level rise*: The effect of global warming on the melting of the ice caps is well-known. Estimates are that a tidal rise of 2 mm per year will occur. In the Basque Country, this means that several hundred hectares of land are due to disappear. According to these projections, then, many fishing villages and harbours will see their existence threatened.
3. *Urban heat island effect within highly populated areas*: Human activity, when highly concentrated – i.e., more than 15,000 people per hectare – can produce more heat than a settlement is capable of dissipating. If urban areas are located on the coast, sea winds can lower this effect, while in highly industrialized areas, the opposite can occur. During summer nights this means an average of 8°C higher than in the surrounding hinterland. This effect can lead to health problems (see Fig. 26.2).

Recommendations for adapting cities to these hazards have been improved with risk management criteria and by considering mitigation strategies. Within this analysis, urban climate adaptive recommendations are structured under five aspects:

1. Mitigation measures
2. Adaptive management recommendations
3. Urban adaptation to the heat island effect
4. Urban adaptation to the sea level rise
5. Urban adaptation to river floods

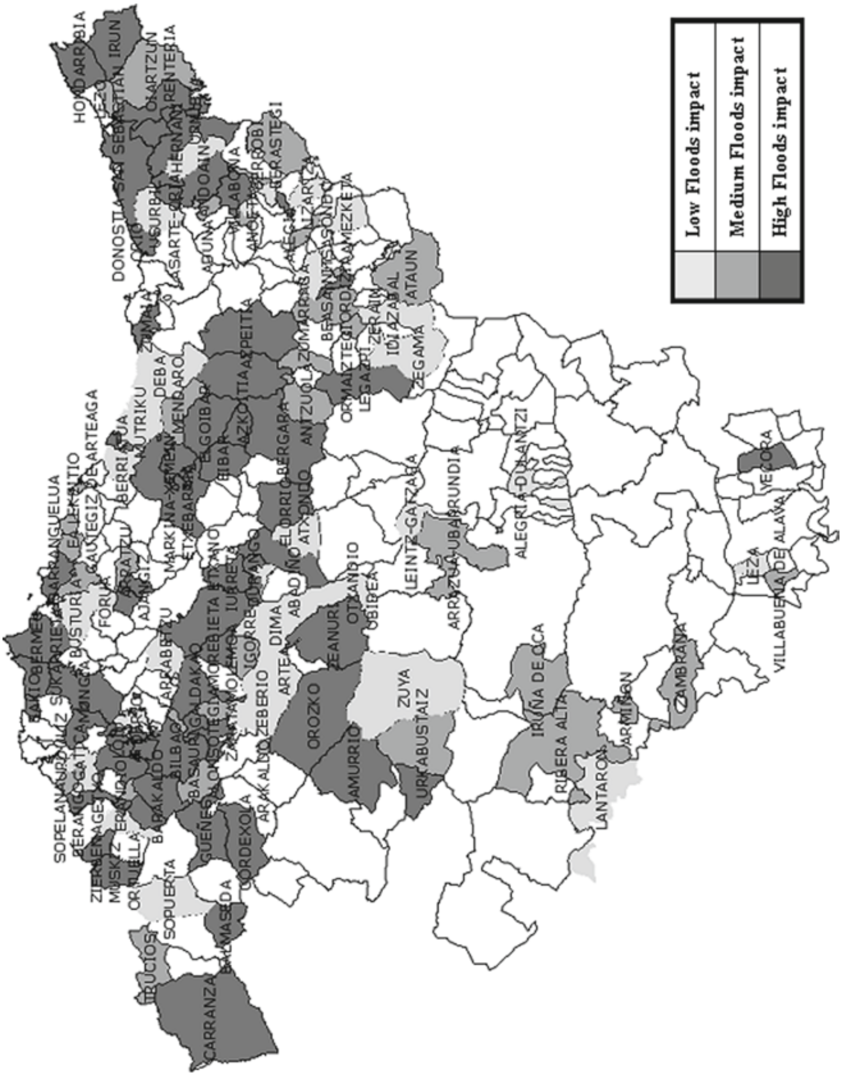

Fig. 26.1 Results of the flood risk study: 150 out of 251 municipalities affected

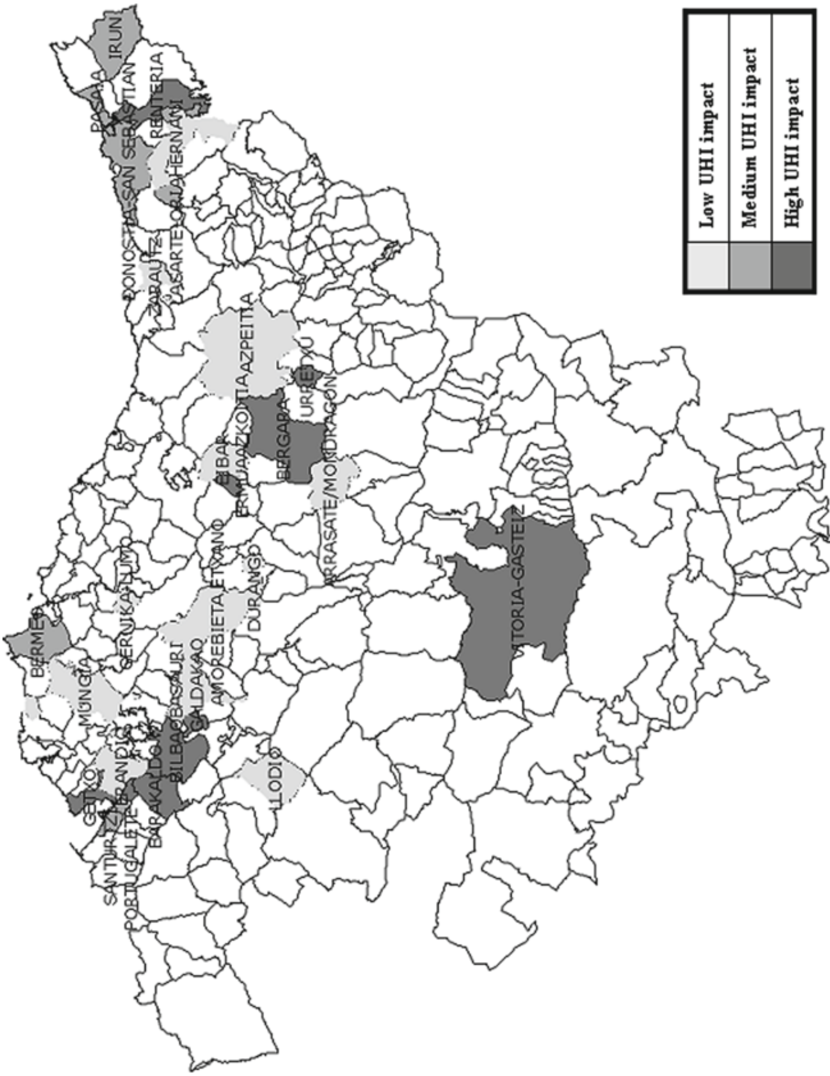

Fig. 26.2 Results of the urban heat island study: 80 out of 251 municipalities affected

These measures and recommendations are in direct relation to urban planning considerations, which take into account the following:

1. Consequences of land use on surroundings – conflict and compatibility
2. Transport and service infrastructure – linear dimension and hub connections
3. Carrying capacity of the wider territory – ecosystem balance
4. Availability of resources within consolidated urban plots – supply and demand
5. Social and environmental needs – quality of life, mobility, economy and production

The management of these issues is heavily dependent on participatory and inter-institutional tools with communication between experts, private agents and public bodies. This approach is needed in order to reach the entire affected population. A global recommendation that is applicable to most situations is the development of an urban adaptation plan. The measures and interventions arranged in this sort of document need to be adapted to changing circumstances. This might require the establishment of some type of information exchange hub – say, a climate change information office – where citizens could exchange knowledge, best practices, and developments within the expert community. Education and awareness programmes should also be started within schools and customized to social class and age.

The expected impacts of this project in the short-term are, on the one hand, an increased awareness and participation of different stakeholders and, on the other, the dissemination of the results of the project among Basque municipalities, environmental agencies and the general public.

At the mid-term stage, this project should promote an increase in environmental research at the micro-scale, including atmospheric simulations, rain scenarios, demographic prognoses, and mobility plans. In the long-term, recommendations are expected to be adopted within the municipalities. As the threat of extreme weather events becomes increasingly clear, funding is expected to increase for the implementation of more specific measures. At the same time, these initiatives will bring benefits and employment to the engineering technology and consultancy markets.

26.3 Local Initiative 2: Development of a Methodology for the Implementation of Local Adaptation Strategies

The second local initiative involves the development of a methodology for the preparation of local climate change adaptation programmes. This is based on the results of Local Initiative 1 on urban vulnerability assessment (described in the previous section) as well as the Programme for Adaptation to Climate Change of the Basque Country. The intention of this initiative, which is now at an early stage, is to provide municipalities with the tools needed to include adaptation into their management work. This approach fits into the planning instruments already in place, particularly the Local Agenda 21 Action Plan, which has already been accepted by most Udalsarea 21 member municipalities. The main points of the methodology are:

1. Definition of motivating factors for adaptation and developing arguments that stress the importance of including adaptation into municipal management.
2. Identification of elements that can help to incorporate adaptation through various degrees of commitment, according to individual circumstances. This means prioritising and making accessible a methodology which turns adaptation into action through specific local action plans or climate change adaptation programmes linked to Local Agenda 21.
3. Depiction of potential adaptation measures for municipalities. These consist of two basic types: (a) 'no regret' measures – measures that entail more benefits than costs, even in the absence of impacts from climate change – and (b) 'low regret' measures – measures that entail relatively low cost with high potential benefits under projected climate change.

This methodology will be piloted at volunteer municipalities and adjusted to meet their specific needs. Following this trial period, the methodology will become available to all municipalities through the resources provided by the Udalsarea 21 network.

26.4 Conclusions and Future Steps

Both initiatives have been promoted to cover several activities identified as key for climate change adaptation at the local level in the Basque Country. Such activities can be summarized as follows:

1. Preparation of a methodological framework to assess vulnerability to climate change at the municipal level
2. Systematisation of typical impacts of climate change and classification of municipalities by type in line with their vulnerability to climate change
3. Development of methodological directives to formulate local strategies of adaptation to climate change
4. Definition of criteria for the implementation of actions to combat climate change through urban planning
5. Dissemination of information through workshops among the Udalsarea 21 netw.ork of municipalities and between leading stakeholders

The following have been identified as key success factors:

1. Engagement of the main stakeholders in assessing vulnerability profiles and drawing up methodological instruments
2. Top to bottom alignment of initiatives and policies at the regional scale for adaptation to climate change, particularly the programme for adaptation to climate change in the Basque Country

3. Alignment at the peer level and valorisation of all initiatives and instruments already in place in local management and policies at the municipal level
4. Piloting efforts in the preparation of the methodology
5. A philosophy that seeks to provide cost-effective methodological instruments that can be viably incorporated with policies for adaptation to climate change
6. Coherence and alignment of mitigation and adaptation policies (Yohe and Strzepek 2007; Revi 2008)

Similarly, we consider that the major challenges in urban areas are, on one hand, defining the best framework for action and on the other hand, identifying opportunities that make the best use of technologies. The Basque experience shows that the best combination of strategies and procedures needs to be identified in a way that increases the efficiency and effectiveness of adaptation actions. An institutional framework which promotes this behaviour should enhance municipal adaptive capacity to make it more flexible and responsive to sudden changes. It is also essential to establish a continually updated knowledge base of the impacts of climate change on our regions, coasts and ecosystems. This process is crucial for detecting new and unknown vulnerabilities of ecosystem services, communities, the built environment, as well as the economy. The Basque Government has promoted the initiatives described in this paper and has made efforts to establish a policy framework that addresses the issue of adaptation. Furthermore, specific legislation on climate change – i.e., the Programme for Adaptation to Climate Change of the Basque Country – is expected to come into force in 2011. These efforts should be reinforced through the broadest possible mobilisation of stakeholders.

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Chapter 27
Climate Change Adaptation in Dutch Municipalities: Risk Perception and Institutional Capacity*

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Abstract This contribution presents case studies of nine Dutch municipalities. Interview-based data show that the drivers of local climate adaptation in these cases are determined more by local contextual factors than by past experience with flooding or an expected increase of climate change risk. The presence of larger institutional capacity did not prove to be determinative of the level of action in climate change adaptation policies. Only in urban cases where a green party administrator was responsible for environmental affairs was a high level of 'adaptation action' observed. Another mediating factor appeared to be the variation in quality of climate change information.

Keywords Adaptation • Adaptive capacity • Climate change • Local government • Risk perception

27.1 Introduction

Climate change is real. Rising sea levels, increasing average temperatures and more severe weather events are already occurring. Moreover, north-western Europe is experiencing rising temperatures that exceed the predictions of some climate change scenarios. Even if we were to cut our emissions of greenhouse gasses today, climate change would continue due to the accumulation of gases emitted in the past. Because of this, the need to take adaptation measures is urgent (IPCC 2007).

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Although national governments are now taking a lead on the issue of climate change adaptation, the European Commission has emphasized the crucial role of local authorities (COM 2009). The Dutch National Adaptation Strategy, too, has referred to the importance of local level government (Ministry of VROM 2007). The local level is considered to be essential since it is where the most comprehensive information on local characteristics is available, where civil awareness can be most effectively raised and where impacts are most felt. As Næss et al. (2005) argue: while a country can, as a whole, often be considered resilient, its local communities can nevertheless be at risk due to local economic conditions, geography and the state of infrastructure.

Local adaptation to climate change has recently drawn considerable research attention (e.g., Adger and Vincent 2005; Adger et al. 2005; Wall and Marzall 2006; Wilson 2006; Smit and Wandel 2006; Amundsen et al. 2010). Yet very few studies address how local institutional capacity affects levels of preparedness. Therefore, this study focuses on local adaptation strategies by exploring the effect of institutional capacity on local initiatives in the Netherlands. We aim to offer an enhanced knowledge base for scientists and politicians occupied with the development of local adaptation strategies.

In what follows, the research design and methodology is briefly outlined and the circumstances surrounding Dutch local adaptation efforts to climate change are discussed. This is followed by an overview of the findings of local preparedness. Finally, conclusions are drawn and some concluding remarks made on the role of Dutch local governments in the context of a changing climate.

27.2 Research Design and Case Selection

The research design of this study started from the premise that the impacts of natural, weather related events are nothing new, but that due to the influence of climate change, future events are likely to occur with greater frequency and impact. We chose to focus on flooding events since these have occurred in the past and will increasingly occur in the future. This allowed us to relate past experiences of severe flood impacts with the future probabilities of climate change induced flood risk. The past floods have been recorded in the International Disaster Database EM-DAT[1].

We selected cases based on three variables in order to determine the extent to which they drive adaptation efforts. First, the *history of exposure* dimension was operationalised in relation to the 1953 North Sea Flood and the 1993/1995 high waters – events that could be assumed as 'settled' in the institutional memory of the relevant cases.[2]

[1] This database can be found online at http://www.emdat.be.

[2] In 1953, parts of southwestern Netherlands flooded resulting in 1,800 casualties. In 1993 and 1995, the high waters threatened the river dykes in the middle of the country. During the 1995 'near-flooding' event, the largest postwar evacuation in the country took place: 250,000 people (and a million livestock) were forced to move.

The impacts of flooding events resulted in the definition of two potential research areas. Second, we differentiated the dimension of *increased risk.* This was operationalised by studying the 'risk map' that shows flood-prone areas – among many other types of risk[3] Third, the dimension of *size* was operationalised according to the size of the local population. This resulted in a group of urban and a group of rural cases. The combinations of these three dimensions lead to a preliminary scoping of relevant municipalities, resulting in the selection of nine municipalities that would form our cases for the study.

27.3 Climate Adaptation at the Dutch Local-Level Government

Climate change impacts in the Netherlands are mainly associated with the increased volumes of water that are expected to enter the country through precipitation, river discharges and sea level rise. Hence, both the national government and the 2008 Delta Committee[4] primarily address the flood prone, lower-lying areas near the coast and the larger rivers[5]. Climate change impacts, however, will be experienced locally throughout the country. The Netherlands Scientific Council for Government Policy addresses these local impacts in their report on climate change (Ministry of AZ 2006), declaring that municipalities themselves should develop local strategies to cope with climate change; e.g., altering water systems and changing agricultural activities.

In 2007, the Dutch local level (consisting of 441 municipalities) agreed to meet national climate adaptation targets by signing a climate agreement with the national government. With this commitment, the Dutch local governments agreed to inventory climate adaptation measures that fit with its existing policies (Klimaatakkoord 2007). The agreement also states that, of all governmental layers, the local level can best set an example[6] as it has the closest connection to civilians and companies, and is considered to be the most capable of stimulating local climate change actions.

[3] These regional risk maps are available at http://www.risicokaart.nl (in Dutch only).

[4] The Delta Committee was appointed in 2007 by the Dutch Cabinet as the Sustainable Coastal Development Committee, with the mandate to formulate a vision on the long-term protection of the Dutch coast and its hinterland. In 2008, it presented its advice and with that the committee was adjourned.

[5] The current water embankments are not designed to withstand sea level rise or structurally higher water levels. In 2008, the Delta Commission therefore recommended the national government to enforce all dykes tenfold (Deltacommissie 2008).

[6] The agreement also mentions sustainable procurement and energy saving measures in utility buildings as examples of local action.

27.3.1 Law and Financial Limitations for Local Climate Adaptation

The Municipal Act (1851) is the legal basis for local governments in the Netherlands. While the act demands that municipalities should carry out certain environmental tasks, it does not cover any climate related issues. The Disaster Act (1985) prescribes municipal responsibilities in the case of disasters and severe accidents, yet it also excludes climate change risks, since it only addresses the possibility of 'regular' flooding and extreme weather events. The most important law with respect to the environment, the Environmental Conservation Act (1993), also leaves out any climatic issues. Currently, then, there is no applicable law to constitute a legal basis for climate change adaptation measures. Besides this legal deficit, the existing legislation is considered to be insufficiently flexible in dealing with a changing climate (Verschuuren 2007).

The legal deficit was also observed in practice: several interviewees mentioned lacking access to the necessary tools required to enforce adaptation measurements within their communities. As a consequence, they claim, their municipalities are incapable of sufficiently implementing adaptation strategies; for example, they cannot force property developers to construct climate proof houses. This lack of a legal justification also has an effect on local administrators who, as a result, tend to shift priority away from climate adaptation policies, instead focusing on the tasks required by higher level governments.

At the local level, climate adaptation policy has limited funding since it is a voluntary activity. Dutch local governments largely depend on the national government for their finances: 68% of the lower governments' income originates from the national government – a rather high percentage in comparison with other EU member states (CBS 2008). Most of this funding is earmarked and must be used for the implementation of prescribed tasks. Another 9% of the lower governments' income originates from its own taxes; this is the lowest percentage in the EU – save Malta, which has a very small local governmental layer.

27.3.2 The Role of Municipality Units in Climate Adaptation

In general, Dutch municipalities throughout the Netherlands associate climate change impacts with larger quantities of rainfall and the chance of increased heat waves. As a consequence, the departments concerned with adaptation policy in municipalities are the spatial planning and environment units. However, when looking at the tasks and duties of a municipality, more units could be involved in climate adaptation strategies. These could include: disaster management, public health, and economic affairs.

For this study, we took a closer look at two of these overlooked units. First, we examined the domain of public health. The local health care system is organized in the Public Health Services (in Dutch: Geneeskundige en Gezondheidsdienst;

see GGD 2009). Information on local GGD departments is provided by the National Institute for Public Health and the Environment (in Dutch: Rijksinstituut voor de Volksgezondheid en Milieu; see RIVM 2009), which is the principal centre of expertise on health, nutrition and environmental protection in the country. So far, the RIVM has published reports on the effects of climate change on the health of the Dutch population. Because of its close ties with the RIVM, the GGD appears to be well-informed on the effects of climate change and public health. However, preventive health actions are rarely assigned by the municipality itself. Out of the nine cases studied, only one regarded public health to be an issue for the local climate adaptation strategy. A respondent from the Twente GGD confirmed that no municipality requested additional actions from them.

Second, we examined the disaster management unit, which is also an important local actor. The cases demonstrated rather limited participation from this policy unit. In one of the urban cases, the municipal safety department consists of 20 officers whose work it is to compose and revise the local contingency plans. According to one of the officers, climate change is currently perceived as being 'too big and too slow' to take additional measures. Coping with extreme weather and flooding events is also considered by many to be covered sufficiently within the existing contingency plans.

27.4 Key Findings from the Study

By selecting cases on the dimension of *increased risk*, we aimed to determine the effect of increased risk on the level of adaptation action. However, when comparing high-risk cases to low-risk cases, no clear distinctions can be observed. Compared to the low-risk cases, the five high-risk cases show a larger general awareness of the increased risk. However, climate change induced risks are still not perceived as major threats – though protection *is* expected from the national government. The two high-risk urban cases distinguish a broad range of climate change effects that will affect their area, yet they show differences in their sense of urgency; one is quite carefree about its risk profile and vulnerability, the other is significantly more concerned. This difference can be explained by the lessons learned from experience: the 'carefree' case fully counts on national protection, whereas the other – which has experienced flooding in the past – feels a need to act autonomously. Increased risk, then, did not appear to make a large difference. Even so, the two low-risk urban cases appear to be very active with climate policy, despite the absence of an 'over-average' risk from climate change.

Another key concept we studied for each case was institutional capacity. In our study, we have considered this concept quite broadly: it refers to the governing systems, the resources and manpower of a municipality, and the quality of knowledge present. We found a major division between the rural and urban cases. Compared to their urban counterparts, the rural communities clearly have less manpower and limited means to implement their tasks. It is quite standard here, for instance, that one civil servant may be fully responsible for climate change adaptation.

This obviously limits the capacity to maintain a relevant network and improve the necessary knowledge skills. It also explains the low levels of concern over climate change in the rural cases, and the correspondingly low sense of urgency for adaptation strategies.

Our analysis made the importance of institutional capacity very clear. In the urban cases, there is a greater understanding and awareness of the threats from climate change and literally more hands to work on the issue.

In addition to risk awareness and institutional capacity, though, the cases show that we must add another dimension of action. We saw some degree of risk perception present in all cases but even when sufficient institutional capacity was (considered) present, this did not imply that the issue was given high priority. This can be explained by the fact that knowledge of a particular risk does not automatically lead to action. Lorenzoni et al. (2007) state that adaptation action is only taken when (1) risks are known and (2) resources are available to minimize these risks.

However, in our cases we found a third condition that is crucial; namely, a sense of urgency. We connected this condition to a certain feeling of responsibility, which can lead to action. In each case, a certain awareness of increasing climate change risks was present – and all interviewees showed clear awareness of the importance of climate change impacts – but only for some was a lack of adaptive means considered to be a major barrier. In fact, only when the local administrators considered climate adaptation to be their own responsibility was adaptation placed on the political agenda. Only under this condition did a sense of urgency arise over a lack of resources. For instance, the two urban cases that experienced flooding in the past express a clear sense of urgency and state that a lack of resources is the major obstacle for action.

Furthermore, the presence of a green party administrator responsible for environmental issues – and a more favourable political environment in general – proved to be the most decisive condition in explaining the different levels of action within the urban cases. Green party representatives might feel stronger responsibilities towards climate change protection than those from other political parties – this relates to the third condition we distinguished above. Cities are more likely to have a 'green-minded' administrator since the green party receives more votes in cities than in rural areas. If large enough to be part of the local coalition, the green party almost always receives the portfolio of environmental affairs. One out of the four urban cases we studied did not have a green party administrator – here we observed that the level of action was not as high as in the other urban cases.

27.5 Discussion and Concluding Remarks

Knowledge proved to be a key element in institutional capacity for climate adaptation action. In each case studied, a general knowledge of climate change impacts was more-or-less present and each appeared to have their own sources of knowledge.

Knowledge of specific challenges was more limited, and knowledge of potential instruments of adaptation was only present in a single urban case – i.e., the case that combined both past experience and increased future risk.

Concerning the spread of general and applied knowledge of climate change adaptation, the respondents in many cases expressed a wish to learn from one another and from frontrunner examples, but there are barely direct connections between the frontrunners and others. More effective means of dissemination and across-government communication are therefore necessary. Where knowledge and manpower exist, so does the potential for effective action. In this respect, the urban and rural cases showed a striking difference: in rural communities, one civil servant may be responsible for the environment, spatial planning and housing, while in urban cases, entire policy units may be responsible for the same tasks.

The question is how decisive this difference in capacity is, since rural communities face challenges and solutions of a rather different scale. The less active role of small communities is probably also related to an important social component, namely, strong social solidarity and the tendency to trust past experience when coping with extreme weather and flooding events. Given their larger economic vulnerability, higher population density and greater experience with natural disasters and impacts, it appears that urban communities are developing their own particular culture of civil protection.

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Chapter 28
Toward a More Flood Resilient Urban Environment: The Dutch Multi-level Safety Approach to Flood Risk Management

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Abstract The new EU Floods Directive requires flood risk reduction for areas where risk is deemed significant; for these zones, flood risk management plans must be prepared. In line with these requirements, the Netherlands has opted for a 'multi-level safety' approach, which includes prevention, protection and preparedness responses. This paper describes the application of the multi-level safety approach to the case of the Island of Dordrecht in the Netherlands. For this case study, the flood risks were mapped based on flood depth and arrival time. The results of the risk mapping show that nearly the entire island is at high-risk. A further area perspective map recommends focusing on national- and regional-scale measures for the Island of Dordrecht. Following these results, this paper examines the effectiveness of two alternative regional-scale responses to flood risk reduction: On the one hand, the complete reinforcement of the primary dike ring, and on the other, a partial reinforcement together with a compartmentalisation dike. It is shown that both options can significantly reduce the expected annual damages and number of casualties. The cost-efficiency of each has also been investigated. In this regard, it is concluded that the combination of a partial reinforcement and a compartmentalisation dike is economically feasible.

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Keywords Compartmentalisation • Delta dikes • Integrated flood risk management • Resilience • Urban areas

28.1 Introduction

The European Commission has stressed the need for an integrated approach to flood risk management. The new EU Floods Directive endorses a step-wise approach for managing flood-related risks to human health, the environment and the economy. It will require EU member states to prepare flood risk management plans for areas where risk is deemed significant. These plans are meant to include appropriate objectives that focus either on the reduction of the likelihood of flooding or on the reduction of potential adverse consequences – as well as measures for achieving the established objectives. They are meant to address all phases of the flood risk management cycle, but focus particularly on prevention, protection and preparedness.

In line with the Directive's requirements, the Netherlands is now opting for a 'multi-level safety' approach, which is laid out in its National Waterplan. This is a three-tier approach to flood risk management. The first layer focuses on flood avoidance and remains the cornerstone of water safety policy in the Netherlands (i.e., *prevention*). The other two layers are aimed at limiting the effects of flooding; the second is intended to create a sustainable spatial layout of the Netherlands (i.e., *protection*), and the third seeks to improve the organisational preparations for potential flooding (i.e., *preparedness*).

Because of its broad scope, the Dutch multi-level safety approach requires multi-actor based work across multiple locations. In this respect, the EU's recently initiated Interreg IVB project, MARE, provides a relevant practical example of the application of a multi-level safety approach through the collaboration of public and private stakeholders. These include local, regional, and national authorities, a water board, a regional safety authority, research institutes, and a project developer. The proposed activities will result in the development of a flood risk management plan aimed at creating a more resilient urban environment, one in which floods – even those exceeding design levels – will result in minimal physical and social damage.

This paper offers an analysis of the current flood risk for the Island of Dordrecht and the cost-effectiveness and efficiency of possible responses to manage that risk. The response alternatives investigated within the context of the EU MARE project are (1) to completely reinforce the existing dike ring and to transform it into an overtoppable Delta dike, and (2) to partially reinforce the existing dike ring, combined with a compartmentalisation dike along the Wieldrechtse Zeedijk. These two responses were schematized in SOBEK-RURAL modelling software to analyse the extent to which management of flood risk is possible. This information can then be used as input to develop and update flood risk management plans for specific locations.

28.2 Flood Risk Analysis, Mapping and Management in the Netherlands

In the Netherlands the Flood Directive is being implemented in three phases:

1. Legal incorporation into national legislation;
2. Flood hazard and risk mapping; and
3. Flood risk management planning.

Currently flood hazard and risk maps are being produced. The hazard maps give information on the physical aspects of a potential flood such as flood extent, maximum flood depth and flow velocity. The risk maps focus on the consequences of a potential flood such as the potential number of victims and damages. The next step will be to define flood risk management plans (phase 3). This requires an overview of possible measures, their effectiveness and applicability, as well as insight into the problem definition per area. Overviews of possible measures have been made by Pols et al. (2007) and Van de Ven et al. (2009).

The Netherlands Environmental Assessment Agency (PBL) has developed a risk zoning method to identify areas with similar hazard or risk characteristics in relation to potential casualties (Gaalen et al. 2009). Risk areas are characterized by the maximum water depth and arrival time, variables which have the greatest influence on casualties in the Netherlands. For the variable 'maximum water depth,' three classes are defined: deep (more than 2 m), middle deep (0.5–2 m) and shallow (less than 0.5 m). For the variable 'arrival time,' a threshold level of 9 h is adopted. If a flood arrives within 9 h then it is assumed that inhabitants have little time to safely relocate by foot. The six resulting risk zones are distinguished in Table 28.1 below.

Per area, appropriate strategies and measures can be defined resulting in an area perspective map; e.g., deep and undeveloped areas are designated to remain undeveloped, while for shallow and slow areas the focus might be on vertical evacuation. An area perspective map can be used to gain an overview of strategic choices and measures per risk zone. It can also be used to determine at which scale (national, regional or local) the measures need to be implemented.

28.3 Case Study Application for the Island of Dordrecht

Dating back to the twelfth century, Dordrecht is one of the oldest Dutch cities. Surrounded by a series of rivers and canals – the Oude Maas, Beneden Merwede, Wantij, Nieuwe Merwede, Dordtse Kil – the city is effectively located on an island

Table 28.1 Risk zone classification based on flood depth and arrival time

Deep and fast	Middle deep and fast	Shallow and fast
Deep and slow	Middle deep and slow	Shallow and slow

Fig. 28.1 Rivers Rhine and Meuse. Island of Dordrecht is indicated in dark grey

(Fig. 28.1). The current population of Dordrecht consists of around 118,000 inhabitants. Most residential areas are located in a single polder area of about 6,944 ha in total. The polder is protected by a 37 km long primary dike-ring. The Island of Dordrecht lies in the transition zone between the tidal reach and the river regime reach where the extreme water stages are influenced by both the river runoff and the sea level. The flow direction depends on the discharge of the Rhine and (to a lesser extent) the Meuse. Water flows toward the sea during low tides via the Nieuwe Waterweg (Maasmonding) and through the locks in the Haringvliet. The Maasmonding is an open outlet. The discharge at the Haringvliet locks depends on the Rhine discharge at Lobith. The locks are shut when the river discharge is low (<1,200 m^3/s). The locks are fully open at a Rhine discharge of 10,000 m^3/s. The flow direction changes when the Rhine discharge at Lobith is larger than 4,000 m^3/s. From this point onwards the river discharge starts to dominate the incoming tide flow.

The risk zoning method developed by the Dutch Environmental Assessment Agency has been applied to the Island of Dordrecht and surrounding areas (Pieterse et al. 2009). The results of the risk zoning show that almost the whole of the island is at high-risk, where flooding would either occur deep and slow or deep and fast. A further area perspective map recommends focusing on national- and regional-scale measures for the Island of Dordrecht, such as building Delta dikes and/or compartmentalising the dike ring.

Delta dikes are reinforced dikes that are virtually incapable of breaching. This means that even in the case of a flood event exceeding design thresholds, such a dike would substantially lower the volume of water entering the polder area (Silva and Van Velzen 2008). This can reduce flood extent and inundation depths.

Furthermore, observed flood velocities are expected to lower, limiting risk to casualties and the structural failure of buildings.

Compartmentalisation divides dike ring areas into subdivisions by using, whenever possible, existing line elements such as railway lines, roads, and regional dikes (Oost and Hoekstra 2009). While these structures may already be present in the landscape, they generally require adaptation for their new function as compartmentalisation dikes. This strategy aims to reduce the effects of a dike breach. In the case of an extreme flood event, say, only part of the whole area is inundated, limiting potential damages. This also grants additional time to implement coping measures.

Following the results of the risk zoning exercise, this paper aims to study the effectiveness of two response options: (1) converting the existing dike ring into an overtoppable Delta dike; and (2) a partial conversion of the dike ring into an overtoppable Delta dike *in combination with* compartmentalisation. These two options are compared with the current situation (the Do-Nothing approach). The three alternatives can be summarized as follows (see also Fig. 28.2):

0 – *Do-Nothing*: This is the base case alternative. Dordrecht is protected against a 1 in 2,000 return period discharge, plus a 0.5 m freeboard[1] (except for the Voorstraat with freeboard of 0.3 m) by the primary dike ring as shown in Fig. 28.2 (left-hand side). This dike is around 37 km in length and can breach due to several mechanisms including overflow, sliding of the inner slope, and piping (Silva and Van Velzen 2008). For this alternative, 13 breach locations determined by VNK2 project were used to simulate the inundation processes. In the final simulations, breach locations 1, 2, 3 and 13 were excluded due to the (virtually) unbreachable nature of these dike sections. A critical flow rate of 0.2 m/s (which implies a sandy body) was assumed for breaching.

1 – *Making the existing dike ring overtoppable*: In this alternative, the complete dike ring around the Island of Dordrecht is transformed into an overtoppable Delta dike (Fig. 28.2, middle). It is assumed that the probability of failure of an

Fig. 28.2 Illustration of alternatives 0 (*left*), 1 (*middle*) and 2 (*right*). The *bold lines* indicate the location of overtoppable dikes

[1]Freeboard is the vertical allowance added to the design flood level to allow for hydrologic and hydraulic uncertainties.

overtoppable Delta dike is 100 times less than for the current design standard. To withstand failure due to sliding of the inner slope or piping, the construction of an inner berm is required up to 15 m wide and 2 m deep. The total direct and indirect costs of an inner berm amount to approximately 2.1 million €/km (Silva and Van Velzen 2008).

2 – *Overtoppable dike in combination with compartmentalisation*: In this alternative, the Wantijdijk and Kildijk are reinforced to become overtoppable dikes (see alternative 1) while the Wieldrechtse Zeedijk is used as a compartmentalization dike (Fig. 28.2, right-hand side). For the dike ring area, this means that the area is divided into two compartments of more or less equal dimensions: a northern compartment that contains the urban area, and a southern compartment that contains a more rural area. It is assumed that reinforcing the Wantijdijk and Kildijk virtually eliminates all breach locations along the northern compartment. It is furthermore assumed that the compartmentalisation dike is high and steady enough to hold flood water in the case of a dike breach in the southern compartment.

28.4 Results and Discussions

The three alternatives have been studied by performing hydraulic simulations for a range of flood events, focussing initially on the flood depths and lead times resulting from breaching and/or overtopping. The range of studied events is currently associated with return periods of 2,000 years and beyond. For lower return periods, no flooding is expected to result from breaching and/or overtopping. Although the probability of flooding is extremely low for the Island of Dordrecht, Stone et al. (2008) have shown that expected sea level rise in combination with increasing river discharge (due to climate change) could decrease return periods for this area by a factor 200 by the year 2100. This would increase the probability of flooding significantly. However, this information has not yet been incorporated into the current study.

Figure 28.3 shows the results of the flood modelling and mapping phase, using the risk classification described in Table 28.1. Table 28.2 depicts the flood risk

Fig. 28.3 Differentiation of at-risk areas for the 2,000-year flood

Table 28.2 Expected annual damage and expected annual number of casualties

Alternative	0 (Do-noting)	1 (Overtoppable dike ring)	2 (Overtoppable dike and compartmentalisation)
EAD (M€)	0.50	0.01	0.01
EANC (#)	0.078	0.002	0.002

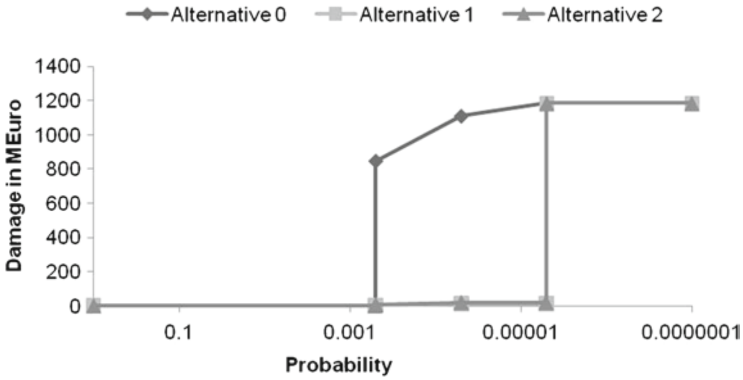

Fig. 28.4 Expected damages over a range of return periods for the three alternatives

estimates for the Island of Dordrecht, in terms of the Expected Annual Damage (EAD) and the Expected Annual Number of Casualties (EANC), using the impact assessment methodology developed for the Netherlands by Kok et al. (2002).

Figure 28.4 shows significant differences of at-risk areas between the three alternatives. While the complete transformation of the primary dike ring into an overtoppable dike (alternative 1) results in almost no flood risk, the extent of potential flood risk for the current conditions (alternative 0) covers practically the whole Island of Dordrecht. For the partial transformation of the dike ring in combination with compartmentalisation (alternative 2), only the southern compartment, which is the agricultural area, is at risk of flooding, whereas the northern compartment, which is the urban area, is protected.

Furthermore, the predicted flood depths, lead times, expected annual damage and number of casualties differ substantially. This can be summarised as follows:

0 – *Do-Nothing*: The combination of large flood depths and short lead times are particularly problematic for the densely populated northern part of the island. Large flood depths cause high levels of damage to buildings, infrastructure and other assets, while short lead times increase the expected number of casualties. Nevertheless, because of the low exceedance probability, the EAD and EANC remain limited.

1 – *Making the existing dike ring overtoppable*: The observed flood extent is minimal. Since flooding occurs exclusively because of overtopping due to wind

and waves, the water volume entering the island is limited. The overall EAD is therefore extremely low (i.e., practically zero) and no casualties are expected for this alternative.

2 – *Overtoppable dike in combination with compartmentalisation*: As a consequence of the combination of a partial transformation of the dike ring with compartmentalisation, the southern compartment becomes completely flooded. Since the southern area consists mainly of agricultural land, the consequences are limited. In the densely populated northern part of the island, there is no flooding. This alternative therefore results in significantly lower EAD and no casualties.

Another key aspect in flood risk assessment – in addition to the EAD and EANC – is the distribution of damages over the range of return periods. The progression of damage over the return period distribution might be even or include threshold effects. This is formalized into the concept of graduality (De Bruijn 2005), in which the damage contribution of single flood events to the overall damage distribution is evaluated. Graduality might serve as an indicator of flood resilience, since it identifies threshold effects in which the system state changes substantially when crossing some stressor level. To gain insight into this aspect, the individual damage progression for the whole range of return periods is shown in Fig. 28.4.

As shown in Figs. 28.4 and 28.5, damages and casualties are not expected below a 2,000 year return period for alternative 0. Beyond this return period, though, the levels increase dramatically. This clearly indicates a threshold effect and therefore results in low level of graduality. A high level of graduality is observed for alternatives 1 and 2, in which the damage and casualty levels only marginally increase beyond the 2,000-year threshold and no significant threshold effects are observed (up to a certain probability). Eventually, at a much smaller probability, the maximum level of damage and casualties will be reached.

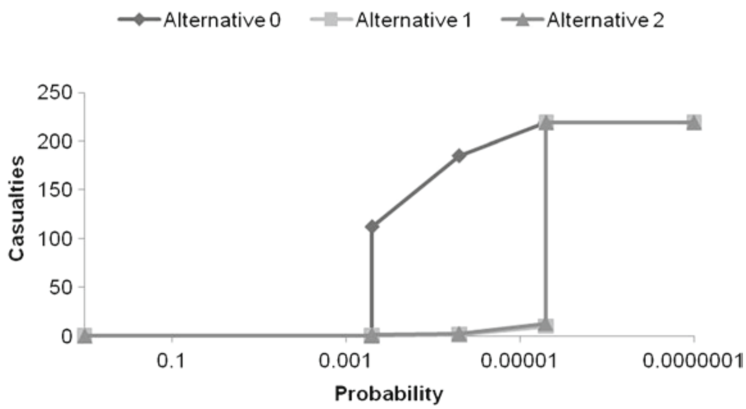

Fig. 28.5 Expected number of casualties over a range of return periods for the three alternatives

Table 28.3 Benefit/cost calculation for each alternative

Alternative	0	1	2
Construction length (km)	0.0	23.0	6.0
Unit cost (M€/km)	–	2.1	2.1
Construction cost (M€)	0.0	47.9	12.5
EAD (M€)	0.50	0.01	0.01
Reduction of EAD (M€)	0.0	0.5	0.5
NVP at 2% discount rate (M€)	–	21.7	21.6
NVP at 4% discount rate (M€)	–	12.8	12.7
NVP at 6% discount rate (M€)	–	9.0	9.0
B/C ratio at 2% discount rate	–	0.5	1.7
B/C ratio at 4% discount rate	–	0.3	1.0
B/C ratio at 6% discount rate	–	0.2	0.7

28.5 Cost-Efficiency of Regional-Scale Measures

In order to investigate the efficiency of the proposed regional scale measures, benefit cost analyses for the three alternatives were conducted. The benefit cost analysis was undertaken over a time horizon of 100 years. The benefit for a response alternative is calculated by estimating the reduction in EAD compared to the base-case alternative (alternative 0). The benefit is then converted into a net present value, using a discount rate of respectively 2%, 4% and 6%. Results of the benefit cost analysis are presented in Table 28.3. These data indicate that for a discount rate up to 4%, the combination of a partial transformation of the dike ring with compartmentalisation (alternative 2) is economically feasible. The complete transformation of the primary dike ring into an overtoppable dike (alternative 1) is not likely to be feasible. However, it is of note that the current benefit cost analysis does not consider the cost of causalities. The likely effects of sea level rise and climate change are also excluded from the analysis. It is expected that both factors will increase the economic feasibility of the response alternatives.

28.6 Conclusions

The current flood protection system for the Island of Dordrecht that consists of a traditional dike ring designed to withstand a 2,000-year event provides relative safety. While sufficient to withstand high and medium probability flood events, the damages and number of causalities expected to occur if the design standard is exceeded are substantial – if not catastrophic. This is due to the fact that flooding generally occurs because of dike breaching rather than overtopping. This causes the island to flood almost completely to significant depths within a short amount of time.

This paper has examined a set of response alternatives to reduce flood risk on the Island of Dordrecht. Each alternative can significantly reduce the flood risks associated with expected annual damage and the number of casualties. The outcomes of the risk modelling phase point to the relative importance of different failure mechanisms and breach locations, as each contributes in its own way to overall expected damages and casualties. Another key aspect in relation to the concept of flood resiliency is the graduality of the observed damage and the casualty distribution over the range of return periods. Currently, substantial threshold effects are observable, signified by a sudden shift in expected damages and number of casualties. These threshold effects indicate a low level of resiliency. The proposed alternatives are shown to have a positive effect by dampening sudden shifts in the state of the system.

The introduction of compartmentalisation and Delta dikes can provide essential safeguarding for the Island of Dordrecht against future flood risk. In particular, when the current urban extent expands (several plans are currently being discussed to develop the city toward the south), the flood protection system will need to be upgraded. The possible future impacts of climate change support this claim further.

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Chapter 29
Climate Change and City Development: Resilience Strategies in Bonn

Rüdiger Wagner

Abstract Global climate change will affect the climate of the Bonn region. The likely forecast for the next five to ten decades shows a climate similar to that of present day northern Italy, that is, a yearly average temperature increase of 2 K. Hotter, earlier and longer dry periods in late spring and summer, increased and stronger precipitation, and warmer rainy winters all require the definition and implementation of strategies and measures for resilient urban structures. The administration of the City of Bonn initiated this process in April 2010 with an expert hearing and a workshop on climate change and city planning. *Stadtklima*, the recently published manual of the Ministry of Environment North Rhine-Westphalia, features a comprehensive compilation of possible actions and instruments, based on a field test in the industrial and urban region of Ruhrgebiet. The next steps in Bonn will include the involvement of public, political and economic stakeholders in the development of the general principle of 'resilient city' and to provide environmentally sound and healthy living conditions in Bonn for the next five to ten decades. Next steps also include the installation of checklist procedures, the improvement of early information and cooperation processes, and the definition of fields of action and criteria for resilient urban structures within the cityscape, such as architecture, traffic ways, water supply, sewer systems, and parks and greens.

Keywords Climate change • Climate prediction • Controversial aims • Resilient city strategy • Vulnerability analysis

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29.1 Bonn's Commitment to Sustainability

As many as 18 UN organizations work in Bonn for sustainable development worldwide, including the Secretariat of the UN Framework Convention against Climate Change. Moreover, about 150 NGOs are based in Bonn. Many of these actors concentrate on sustainability issues, comprising development, environmental protection and social issues. ICLEI is one prominent example within this cluster of organizations committed to sustainable development worldwide. The City of Bonn does not limit itself to playing host to these organizations, but has committed to sustainable development itself, both in local policy as well as in strong cooperation with cities all over the world, e.g., with the cities of Minsk, Buchara, Ulan Bator, Chengdu, La Paz and Cape Coast. Bonn is a member of various city networks, including ICLEI, WMCCC, Eurocities and the Climate Alliance of European Cities. In signing the declaration of accession to the Covenant of Mayors in March 2009, Bonn committed to exceed the climate goals of the EU by aiming to reduce energy consumption by 20%, switching to 20% renewable sources and increasing energy efficiency by 20% – all by 2020. To reach this ambitious goal, the signatory cities have developed a local energy action plan and will report the implementation every 2 years.

Bonn has launched a number of initiatives in past years in order to play an active role in the combat against climate change. Cities play an important role in the global effort to protect the climate; since they have local responsibility for planning, energy supply, local traffic systems and have direct contact to the citizens. In 1995, the political decision was taken to implement a local climate protection policy. In 1996, Bonn acted as a pioneer in the promotion of photovoltaics by cost-effective remuneration. In 1997, a Climate Protection and Energy Concept was adopted. In 2003, Bonn received the European Energy Award Silver Standard (EEA). In 2004, Bonn was awarded with the European Solar Award by EUROSOLAR. In 2007, Bonn adopted its Action Programme on Climate Protection; the EEA-Gold-Award was reached in 2008. In 2009, the second Sustainability Report was published, and recently, an important project was finished that consists of an internet-based solar-roof cadastre that provides information for each house in Bonn as to the ecological and economic feasibility of photovoltaic or solar thermal installations on the roof.

29.2 Will Global Climate Change be Relevant for Bonn?

On December 17, 2008, the Federal Government adopted the German Strategy of Adaptation to Climate Change. At the same time, Bonn's Federal State North Rhine-Westphalia launched programmes meant to analyze expected regional climate changes, their impacts and possible measures to make cities more resilient against these impacts.

The City of Bonn started this process with an internal expert hearing and workshop titled ‘Climate Change and City Planning’ on April 26, 2010. About 50 employees of our City Administration, which included all entities involved with city planning, infrastructure, public greens, healthcare and environmental protection, listened to experts share their state-of-the-art scientific knowledge on the subjects of regional climate change prediction, analysis of vulnerability, and fields of action for adaptation measures. Discussions also took place in three parallel workshops on consequences, possible actions, conflicts of aims and strategies followed.

The first challenge that emerged is arriving at reliable predictions of climate changes at a regional level for the upcoming decades. All predictions are based on modeling, which assume certain conditions and scenarios. The Ministry of Environment of North Rhine-Westphalia entrusted the Institute for Applied Climatology of the University Duisburg-Essen with developing a model for the prediction of regional climate changes. Likely trends can be predicted with the help of this model, but 100% reliable data about the local climate in our cities in the next five or ten decades cannot yet be delivered.

Based on the IPCC Scenario A1B for global climate changes (published in 2007), which constitutes a realistic approach, a global trend could be defined. But scenarios of less or more effective measures against climate change cannot be excluded. The results differ according to the prediction models applied. Six different, but feasible global emission scenarios do exist, 23 different but feasible international models are applied, and model-related mistakes reproduce themselves. There are still gaps in the understanding of all climatic processes, not all processes are representable in the simulations. Nevertheless changes of global temperature and precipitations can be forecasted as a result of multi-model average projections. However, comparing different climate change predictions for certain regions always requires the consideration of the different models and assumptions applied.

On that basis, regional trends can be predicted by numerical computations of physical processes in the atmosphere or by statistical trend analyses and extrapolations. Four different models (two of numerical simulation, two of statistical regression), used by the Potsdam Institute for Climate Impact Research for forecasting climate change in Germany, were applied by the Institute for Applied Climatology for regional forecasts with dissolution of 18 km^2. Thus, a feasible trend could be simulated for Bonn comparing the period 1991–2000 with the period 2051–2060:

- The average annual temperature will increase from 10.5°C to 12.5°C, difference 2 K
- The number of ice days (t max < 0°C) will fall from 5.1 to 1 per year
- The number of frost days (t min < 0°C) will fall from 51 to 31
- The number of summer days (t max > 25°C) will nearly duplicate, from 37.1 to 70.3 days per year
- The number of hot days (T max > 30°C) will nearly triplicate, from 7.8 to 20.9 days per year

- Long-lasting heat periods (days of long-lasting heat with t max > 30°C) will nearly duplicate
- Yearly precipitation will increase from 543 to 653 mm, increasing from December to March, while decreasing in the summer

The trend for the region of Bonn can be resumed:

- Increase of the yearly average temperature by 2 K
- Italian climate
- 80% resp. 40% decrease of ice and frost days
- Summer days will increase by 90%
- Triple increase of hot days
- Increase of tropical nights by 10%
- Increase of days of heat stress from 5 to 8 (by 60%).
- Increase of yearly precipitation by 20%
- Seasonal drift from summer rain climate to Mediterranean winter rain climate
- Increase of rainy days by up to 21%.

29.3 Relevant Impacts

So what is the threat of a northern Italian climate in Bonn? Why do we have to worry about this trend? Being responsible for the future development of our city – providing environmentally sound and healthy living conditions for future generations – means that we must consider the possible impacts of expected climate change in the region. We have to analyze the vulnerability of our city.

In big cities and congested areas, the impacts of the climate change will be more significant than in rural regions. Already, average temperatures in urban regions with high densities of population and buildings are significantly higher than in the less built-up hinterland. The impacts of increasingly intense rain events in densely built districts are often more severe than outside cities. For these reasons, large cities and congested areas especially have to care about resilient urban structures.

In order to approach these challenges, the 'Regionalverband Ruhr', a regional federation of the cities and counties of the industrial region 'Ruhrgebiet', ran a project to develop a manual on adaptation to climate change. This was carried out in cooperation with the Institute for Applied Climatology of the University of Duisburg-Essen, the Institute for Water and Waste Management of the Technical University of Aachen and the German Institute for Urbanistics. The manual was first applied on a theoretical basis, and in a second step underwent a field test in two model cities of the Ruhrgebiet – Dortmund and Bottrop. The results of this test were taken into account in the manual now provided by the Ministry of Environment of North Rhine-Westphalia. It gives helpful hints on the aspects to be considered within the vulnerability analysis and in terms of action to be taken. However, climate, infrastructural and urban conditions differ significantly from town to town, so each region has to identify its own vulnerabilities and needs for action.

What, then, are the relevant vulnerabilities for Bonn? Heat stress may be considered the main problem with respect to several impacts. The most severe impact of the increase in temperature extremes is the higher risk of mortality and morbidity. Elderly people and babies are especially at risk, and women are more affected than men. Early heat periods in the spring represent greater stress on the public's health than in the summer, and the shift of more early hot days to end of April will also lead to more adverse periods of heat. Night temperatures are more important than the daytime maxima temperatures since the recuperation of our bodies in the cooler night is essential for our health.

Heat stress may also affect our drinking water supply. Sustained heat periods can warm the soil and lead to the warming of drinking water pipelines in the soil. This increases the risk of contamination of the drinking water. In warmed water reservoirs like barrages, higher rates of germs and algae may occur after long-lasting heat periods. The use of water for public greens, gardens, parks, and agriculture might increase significantly.

Urban waste water systems, too, will be affected by changes of precipitation and increasingly warmer and rainy winters. Sudden flooding may surpass the capacity of the road drainage systems and may cause severe damage to streets, other traffic areas, basements, underground car parks, bridges and tunnels.

Hygiene problems may also result from the flooding of combined wastewater sewers. Furthermore, rainy winters may lead to higher groundwater levels that threatens low-lying settlements and makes additional pump installations necessary.

Dry periods over several weeks can lead to deposits in the sewer system that are likely to reduce hydraulic performance, causing offensive odors and bug infestation. Local small watercourses as well as drinking resources may be affected by declining groundwater due to the lack of rain and increasing water usage. The desiccation of the soil surface can also lead to increased erosion.

29.4 Measures and Strategies

With expert assistance, the participants in our workshops identified many measures and strategies to create resilient urban structures in the City of Bonn. The manual, too, lists a large variety of measures to be taken on the different fields of action. In our workshops, the focus was on how to reduce adverse warming of the city. Some (not exhaustive) examples that were discussed and proposed include:

- Development of the general principle of 'resilience';
- Actualization of the local climate map and use of the municipal geo-information-system to identify hotspots, aeration lanes, existing or missing but necessary cold isles;
- Inclusion of the resilience relevance in the ecological assessment of compensating area for construction measures;
- Definition and preservation of aeration lanes;

- Preservation and creation of cold isles in public spaces, e.g., on derelict playgrounds and in private backyards;
- Greening of roofs and facades;
- Springs and sheets of water;
- Trees along the streets; and,
- Applying reflective colors on roofs, facades and road surfaces.

Participants realized that a considerable part of the necessary measures were already on the daily agenda and had been realized in many cases. For instance, Bonn has already made efforts toward a sound city climate by providing large public green spaces, 30.000 trees along its streets, a municipal forest managed according to FSC criteria and enforcing strict tree preservation bye-laws.

A broad discussion was also led on how to implement necessary measures and administrative instruments, and on strategies to involve local political decision makers, the local economy, investors and private house-owners. Development plans are surely an important instrument to implement measures for resilience, but since the city is already built, only a rebuilding rate of 5% can be reached. Are legal provisions sufficient for the implementation of resilience measures in the course of construction permits? Can we use the municipal fee system for incentives? Can we use the instrument of city forming statutes for greening roofs and facades? The 'Inner-City Master Plan', which will be developed through broad public participation, will likely be one important instrument for including the principles of resilience in city development planning.

29.5 Controversial Aims

The workshop discussions and the manual both demonstrate that certain measures to create resilient urban structures in Bonn may contradict other aims that attempt to ensure sustainable city development. To reduce heat stress from inhabitants, low density architecture and sufficient free public green spaces for fresh-air ventilation are necessary. On the other hand, compact settlement structures are necessary to reduce traffic and the splintering of land. Cities with decreasing populations have more chances to use free or converted spaces for resilience measures than cities like Bonn, where the increasing population requires more housing. The enhancement of free public spaces and open constructions may also conflict with the aim of noise reduction by closing building gaps along the streets that protect backyards from noise.

Planting deep rooting tree species may also damage existing sewers, water pipes and cable traces. High density greening measures may reduce the exchange of air or can reduce the efficiency of solar installations by shadowing the roofs. The extension of public greens may lead to high water consumption in dry hot periods and may thus be in conflict with reduced water resources.

This non exhaustive list leads to the conclusion that measures for resilience must be implemented on a case-to-case basis in order to find the best solution.

29.6 Organizing the Process

The expert hearing and workshops can only be considered as the start of a common, interdisciplinary and integrative process. Internal administrative measures must follow as well as external measures to increase public awareness and to develop a broad consensus on the general principles of achieving resilience. Discussions about the next steps to be taken have just begun. The main issues will include:

- Involvement of public and political stakeholders
- Defining relevant fields of action for resilient urban structures
- Developing criteria and installing checklist procedures
- Improvement of internal information processes for early cooperation.

29.7 Summary

Global climate change will affect the climate of the Bonn region. The trend for the next five to ten decades suggests a climate similar to that of present day northern Italy, that is, an increase of the yearly average temperature by 2 K. Hotter, earlier and longer dry periods in late spring and summer, more and stronger precipitation and warmer rainy winters require the definition and implementation of strategies and measures for resilient urban structures. The Administration of the City of Bonn initiated this process with an expert hearing and a workshop on climate change and city planning in April 2010. The manual Stadtklima, of the Ministry of Environment North Rhine-Westphalia features a comprehensive compilation of possible ways of action and instruments, based on a field test in the industrial and urban region of Ruhrgebiet. The next steps in Bonn will be the involvement of public, political and economic stakeholders to develop the general principle of ‘resilient city’ and to provide environmentally sound and healthy living conditions in Bonn for the next five to ten decades. Next steps also include the definition of fields of action and criteria for resilient urban structures, the installation of checklist procedures and the improvement of early information and cooperation processes.

Chapter 30
Integrated Climate Adaptation in Dresden: Insights from Flood Prevention

Christian Korndörfer, Peter Teichmann, and Frank Frenzel

Abstract In 2002, Dresden was hit by heavy rains and floods that caused severe and costly damages to the city. This event initiated the establishment of a new municipal water management system to address the various urban flood-risks associated with the city's urban creeks, groundwater, local sewage system, as well as the river Elbe. At the same time, the impact of climate change on urban structures, buildings, ecosystems and the technical infrastructure within Dresden are being systematically researched. This paper shares the first adaptation options being developed in response, specifically as they relate to the action fields advanced within the Dresden Flood Prevention Programme.

Keywords Adaptation • Climate change • Dresden • Flood prevention • Urban planning

30.1 Flood Dangers to the City Territory

The city of Dresden is the capital of the Free State of Saxony in the southeast of Germany. The city has around 506,000 inhabitants. The flooding events of August 2002 revealed the significant vulnerability of large parts of the city territory, as many water bodies were affected to an extent that had not previously been seen (see Fig. 30.1 for the example of the city centre). Many of the efforts and accomplishments of the re-development process begun in 1990 were seriously impaired or even destroyed. Private livelihoods as well as businesses and enterprises were compromised, and century-old cultural assets were affected. The losses in the city

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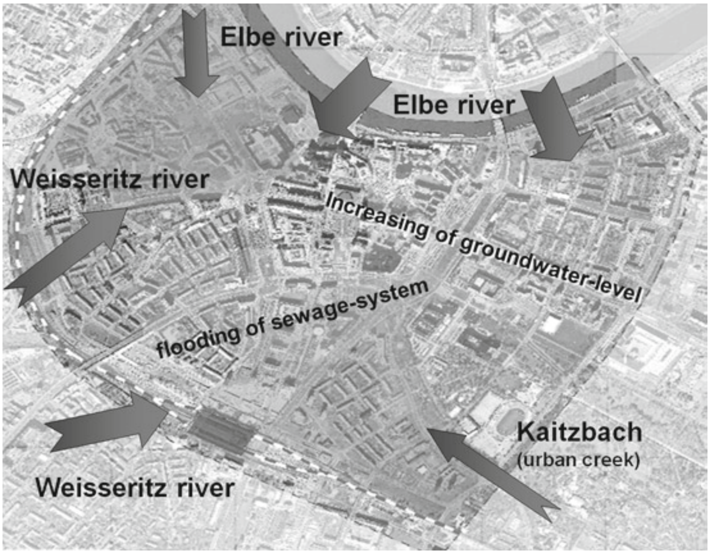

Fig. 30.1 Inundation areas of the floods in August 2002 within the city centre of Dresden and flood dangers in the future (Source: City of Dresden, Environmental Office)

territory were estimated at more than a billion euros. These losses brought clearly into view the deficiencies of flood prevention and defence within the city, as well as shortcomings in the organisation of the authorities within Dresden.

In addition to replacing losses, the city began activities to better identify dangers and inform people on all political and administration levels of the need to address these dangers. Through these efforts, measures to improve flood prevention began to take shape. Legal rules regarding flood protection were also gradually improved.

30.2 Dresden's Strategic Approach to Flood Prevention

The City Council of Dresden decided in May 2004 to work out the Dresden Flood Prevention Programme (DFPP) and to ensure that the city's urban development remains sustainable and competitive in the long term. Its strategic approach is to jointly consider the dangers posed by all water bodies and systems – including the sewage canalisation – and to establish relations to each affected urban area.

Effective protection of these areas is achieved when protection goals take into account all flood dangers. However, risks could remain due to the break down of protection facilities or flooding that exceeds design limits. The management of such residual risks is the current focus of the municipal flood defence plan and in the future will be the subject of the flood risk management plan, according to the EU directive 2007/60/EG. The DFPP already partially meets the needs of this EU directive (steps to take by 2013) and shall be developed in line with the integrated flood risk management plan as part of the municipal risk prevention strategy.

At the beginning of the DFPP process, flood dangers were analysed followed by a description of the required fields of action for flood prevention. Strategies for flood prevention were then developed with respect to specific water bodies and water systems. These included the Elbe River, the rivers Weisseritz and Lockwitz, as well as many urban creeks, ground water and sewage systems.

The DFPP was not conceived merely as a hydraulic engineering solution, but as an *integrated action program* oriented toward urban development. It is aimed at the improvement of flood prevention in a manner that is compatible with the city's interests, economic and otherwise. Flood prevention must be understood as an important part of urban and regional planning procedures, and comprises a large set of possible measures and activities:

- keeping endangered areas free from further settlement; e.g., through the legal designation of flood plains (which cover approximately 10% of the city territory), as well as through improved land use planning
- providing information about flood risks to strengthen individual prevention (duty of individual prevention is fixed by law)
- improvement of run-off conditions
- improvement of retention processes and water storage, especially above settlement areas
- constructional or technical flood protection facilities for the protection of areas, as well as for the protection of individual buildings and properties
- monitoring of all water bodies including ground water. Concerning the transboundary Elbe river, there is close cooperation with certain Czech cities and institutions like Povodí Labe.

The city areas in danger of flooding were subdivided in the DFPP into 22 investigation areas. Tangible assets and inhabitants potentially affected by floods were ascertained for every investigation area. Then, in each case, the measures finished or still to be realized were described. These measures were derived from the protection targets set by the city council in June 2008.

The DFPP concludes by defining the need for action and the necessary capital investments in upcoming years. The DFPP in the future shall contain strategic elements of flood defence planning and shall be developed towards a flood risk management plan according to the EU Directive on assessment and management of flood risks (2007/60/EG). All documents belonging to the Dresden Flood Prevention Programme are available (in German) online at www.dresden.de/PHD. The DFPP was confirmed by the city council on August 12, 2010.

30.3 Flood Prevention for Smaller Urban Creeks

Flood prevention with respect to smaller urban creeks is the direct responsibility of the city administration. Variations in altitude across Dresden's landscape have resulted in a ramified system of creeks that equal 460 km in length. To reduce the risk of damage as a result of flooding, the city of Dresden developed an integrated strategy consisting of several different components.

30.3.1 Near-to-Nature Management of Rainfall Water

In Dresden, any construction work that results in soil sealing must be compensated for. As a general rule, this means unsealing another location in town in order to offset the original soil loss. Home builders must ensure that ground water regeneration and superficial runoff will not be changed significantly due to building development. The concept of near-to-nature management of rain water, which aims to minimize harmful impacts on the water balance, is an inherent part of urban land-use planning. Since 2001, issuing approval for development has required taking these factors into consideration.

30.3.2 Near-to-Nature Development of Water Courses

A special challenge for urban spaces is the development of near-to-nature, ecologically valuable water courses connected with high hydraulic capability in case of flood events. The demand for expanded water courses often conflicts with the needs of industrial agriculture outside the settlement and with existing buildings and streets within the settlement. On the one hand, a minimum of runoff must be ensured (including in drought periods) and fast occurring hydraulic impacts due to heavy rainfalls have to be overcome. On the other hand, losses to bordering buildings need to be avoided. In Dresden, runoff is slowed and buffered by opening the piped parts of water courses and by using retention facilities (as a rule, 'green swales') above settlements. Farmers receive compensation for lower yields and restrictions of land use.

30.3.3 River Development and Retention of Sediments

Facilities to retain sediments are built at numerous water courses above settlement areas to avoid losses to buildings, streets, and the like. To prevent losses during the runoff of floods, water courses have been provided with more space. As a general rule, a protection target of HQ100 (runoff which occurs once every 100 years) is defined.

30.4 Effects of Climate Change – Cause to Improve Flood Prevention

The improvement of flood prevention plans for Dresden is necessary in order to react appropriately to the regional effects of climate change. Despite the efforts and achievements of CO_2 reduction in developed countries, ongoing climate change will continue in the next decades. This will shift the mean values of the relevant meteorological parameters and significantly increase the bandwidth of possible weather events. All German cities and regions will be affected by this development. Information provided by climate scientists indicate a wide variation in rainfall patterns across regions of Germany. Rainfalls (seasonal and mean value for the year) are expected to increase remarkably in the southwest and west of Germany, while decreasing in the east. Climate projections for the Free State of Saxony show the following essential trends until the year 2050:

- further increase of yearly mean temperature of about 2 K above the long-term mean value from 1981 to 2000
- increase of number of summer days and hot days
- decrease of number of ice days and freeze days
- decrease of yearly rainfall sum, especially in already dry regions in the east and northeast of Saxony
- strong decrease of the monthly rainfall sums in spring and summer with increasing occurrence of drought periods
- increase of convective rainfalls in summer with increased flood risks, in general an increase of variance of possible weather conditions (see Fig. 30.2).

The predicted increase of the bandwidth of possible weather conditions is especially grave. That means it will be significantly hotter and drier by trend, but occasionally there will also occur extremely cold winters. The above mentioned changes are the result of complicated processes in the atmosphere and the

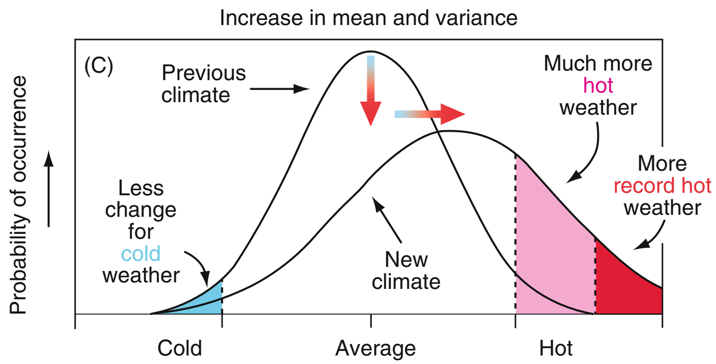

Fig. 30.2 Increase in mean and variance of possible whether events (Source: Epstein and Mills 2005)

Fig. 30.3 Flood of Elbe river, August 17, 2002, water level 940 cm at gauge. Dresden, bridge Augustusbrücke (Photo: City of Dresden, Environmental office)

oceans. Weather conditions not observed before in our regions may occur, similar to the flood in August 2002 (see Fig. 30.3) and the drought in 2005 (see Fig. 30.4).

30.5 Integrated Strategy for Climate Change Adaptation

In light of these long-term trends and the necessity of adapting to the consequences of climate change, the DFPP may be considered as an essential element in the municipality's sustainability strategy. An important step towards such a strategy of sustainability is the ongoing REGKLAM project, currently funded by the German Federal Government[1]. The city of Dresden is part of the project's consortium. This project aims at the development and testing of an Integrated Regional Climate Change Adaptation Program for the Model Region Dresden,

[1] The REGKLAM project is part of the KLIMZUG promoting initiative (climate change in regions) of the German Federal Ministry of Research and Education.

Fig. 30.4 Low water of Elbe river, June 18, 2005, water level 90 cm at gauge. Dresden, bridge Augustusbrücke (Photo: City of Dresden, Environmental office)

carried out and supported by an established network of relevant stakeholders (see www.regklam.de).

The impact of regional climate change on urban structures, buildings, ecosystems and technical infrastructure shall be investigated within the city of Dresden and its surroundings. To overcome the vulnerability of these systems, adaptation options are being developed by a network of researchers and users from administrations and businesses of the region. The action fields defined in the DFPP provide a useful basis to develop action fields for adaptation in the Dresden region. These include:

- protection and development of water bodies for high and low water level and changing quality
- buildings and city-structures
- agriculture and forestry
- water supply and waste water disposal
- economic risks and opportunities
- biodiversity and nature protection
- protection of human health

The methods for implementing adaptation options against the impacts of climate change are similar to those for the flood prevention programme. Some adaptation options and measures can be addressed directly to the users, e.g., in agriculture and forestry, for technical systems and buildings, or for water bodies, if responsibility can be assigned.

Many elements of adaptation are interdependent; e.g., flood protection is connected with land use, and water systems are connected with ground sealing and green cover. Bio-climatic effects are dependent on surface features, the volume of green space in the city and other factors. Dresden is strongly dependent on the surrounding region in most action fields, e.g., in water supply and cold air creation and flow. Sectoral adaptation strategies in these fields are bound to fail, thus an integrated adaptation program is needed for the city and the region. It is necessary to look for synergies and other interests.

The best way to overcome opposing interests is to build up networks with all relevant stakeholders and start implementation with measures that are in the interest of many partners. First results were obtained by the implementation of adaptation options into the existing framework of land use planning, flood protection planning and other planning and legal tools, e.g., for the protection of all water bodies including ground water. The leading idea of the new landscape plan for Dresden is that 'the city will be kept and developed in an ecological net'. The elements of this net include areas with overlapping functions for the development of water courses, the connection of biotopes, green areas for recreation, lanes for fresh air flow, and cold islands. New elements of the net have just been finished, including a remediated brown field, which is now a green link, a lane for fresh and cold air to the inner city, as well as a flood retention space for extreme flash floods.

Reference

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Chapter 31
Integrated Climate Protection Program for the City of Chemnitz: Climate Diagnosis, Climate Change Prognosis, and Adaptation Measures in the Urban Area

Petra Schneider, Nicole Gottschalk, Ralf Löser, and Thomas Scharbrodt

Abstract The scope of this project was the evaluation of the regional needs caused by climate change in the city of Chemnitz (Saxony). A GIS-based method for regionalisation of the prognosis data at the city mesoscale was used. The simulations were elaborated for the diagnosis periods 1991–1990 and 2001–2010, as well as for the prognosis periods 2011–2020 and 2041–2050. The impact evaluation was carried out through a risk assessment of bioclimatic effects. The subject of the study was the evaluation of the expected impacts of climate change, and the development of protection and adaptation measures for the city. The proposed adaptation measures were evaluated in terms of efficiency, acceptance, practicability, feasibility and affordability.

Keywords Communal climate change adaptation measures

31.1 Introduction

Scientific evidence confirms that climate change is already taking place, and most of the warming observed during the past 50 years is due to human activity (IPCC 2000, 2007). In recent years, reducing vulnerability to climate change has become

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an urgent issue and is at the forefront of any sustainable development policy agenda. Adaptation is a process whereby individuals and communities seek to cope with the consequences of climate change and vulnerability. The urban environment has distinctive biophysical features in relation to surrounding rural areas. These include altered energy exchanges that create urban heat islands, and changes in hydrology like increased surface runoff. Such changes are partially a result of the special surface structure in urban area. For example, less vegetated surfaces lead to a decrease in evaporative cooling, whilst an increase in surface sealing results in increased surface runoff. Climate change will amplify these distinctive features.

In February 2008, the City of Chemnitz decided on the elaboration of an Integrated Climate Protection Program that included climate change adaptation measures. The scope of the project considered the regional needs resulting from current and prognosticated climate change consequences in Saxony, which are derived from climate models. For the prognostic calculation of the future urban climate, a GIS-based method was developed and applied. For this purpose, the current and prognosticated changes of the meteorological parameters for the city of Chemnitz have been evaluated. Processing also included the evaluation of the consequences of climate change using the climate impact assessment study elaborated especially for the city of Chemnitz. This forms the basis for the development of protection and adaptation measures for the city.

With around 241,500 inhabitants, Chemnitz is one of the six main centres of the Free State of Saxony, and is the third largest city after Leipzig and Dresden. Located in the northern foothills of the Ore Mountains, it is part of the Saxon triangle metropolitan area comprising 3.5 million people. Considered a 'city of modernity', Chemnitz was and still is an industrial centre, including a car supply and textile industry. The city centre area includes numerous incorporations and no single closed settlement area. The rural settlements (mainly eastern districts) are separated from the inner city of Chemnitz.

This study included the evaluation of the consequences of the expected climate change impacts and the development of protection and adaptation measures for the city. The elaboration of the study considered the following topics:

1. Climate diagnosis and climate prognosis for Chemnitz City, taking into consideration the state of the art in terms of climate change, especially in the urban area (data base climate prognosis data for Saxony);
2. Climate change impact analysis for the relevant environmental factors; and,
3. Risk analysis and conclusion of adaptation measures.

The scope of the study – which was financed partially by the City of Chemnitz and partially by the National Ministry of Environment – was the development of a strategy that included adaptation solutions for preventive measures and hazard management. The purpose of the study was to provide conclusions and practical guidelines for the City Development Concept, which outlines the decisions of the city council based on socio-economic and environmental conditions and summarises the future strategies for the city's development in terms of emission reductions and adaptation to climate change. The general approach of the Integrated Climate Protection Program was the following:

1. Assessment of current climate trends and future projections
2. Undertaking a vulnerability assessment
   (a) Identify current vulnerabilities (in each sector and for cross-cutting themes) based on current climate risks and trends
   (b) Identify future vulnerabilities based on future climate scenarios and risks
3. Strategy formulation
4. Development of adaptation options
5. Evaluation of priority adaptation strategies
6. Programme and project scoping and design
7. Implementation
8. Monitoring and evaluation of interventions

The following content describes the methodology used to realise those steps, the results of the vulnerability assessment, and the development of adaptation measures.

31.2 Methodology and Approach

31.2.1 General Approach, Downscaling, Regionalisation, Visualisation

Several global climate models (GCM) developed in the past two decades have made forecasting future climate changes possible. These models have a large scale and are therefore especially sufficient to make general predications concerning the development of regional meteorological parameters and, alternatively, the long-term changed pressure and stream model of global circulation. To find better regionally valid solutions, a 'downscaling' (regionalisation) was carried out. The State Office for Environment, Agriculture and Geology (LfULG) has provided the corresponding climate prognosis data base for Saxony.

Climate prognosis in the urban area is a special modelling challenge. The factors affecting the urban climate are divided into natural and anthropogenic factors. Among the natural factors, geographical location, relief, altitude and the land use type are the factors that have the most significant impact on the urban climate prognosis. Among the anthropogenic factors, the most significant effect is caused by the structure and density of the buildings, the heat storage capacity of the building material, and the sealing percentage of the natural soil. The radiation budget and heat balance of urban and industrial urban areas are influenced by these factors. The urban climate is also influenced by emission sources (industry, household, cars), which cause – besides CO_2 – emissions of dust and waste heat.

A method for further regionalisation of the climate prognosis at the mesoscale of the city was developed using the data of the climate model, WEREX. This model was elaborated for Saxony. The WEREX model was downscaled using the classification of eco topes (regional sectors with comparable climatic factors).

The impact evaluation included a risk assessment for the concerned environmental factors and sensitive objects with respect to bioclimatic effects. The elaboration of a bio-climate risk map formed the basis for the risk assessment with regard to effects on human health. Bioclimate is defined as the sum of the climate factors which affect the human body, and is determined by temperature, humidity and wind speed. To express the bioclimate was used the mean predicted vote (PMV), which was regionalised for the city area. Using this regionalisation, bio-climate risk maps were elaborated, expressing the risk for humans in the scale: very small, moderate, significant and high. In case of significant as well as high risk were developed measures to decrease the risk to an acceptable level. The GIS based visualisation of the prognosis results was interfaced with the location of sensitive environmental factors, especially humans and objectives used by humans using the climate prognosis data.

31.2.2 Data Base and Data Processing

The spatial simulations of the climatic conditions were elaborated through the parameterisation of the active urban ecotopes. Depending on the building density and its structure, the urban effect increased or decreased. The following input data were the basis for evaluation:

- Digital terrain model ATKIS DGM25 of the investigated area with a resolution of raster 20 m × 20 m.
- Climate data for period 1950–2008 (daily values of air temperature, precipitation, relative humidity, sunshine duration, wind speed, and cloud density).
- Prognosticated climate data for the period 2000–2100.

The City of Chemnitz provided a data base of different GIS topics: topography, land use, municipal organisation, protected areas, hydrologically sensitive areas, ventilation, and planned and realised land use change. Due to microclimatic interactions on the borders of the ecotopes, the raster topic was interpolated using the Inverse-Distance-Method. The simulations were elaborated for the climate parameter of the normal period 1991–1990 and of the period 2001–2010, as well as prognosticated values of decades 2001–2010, 2011–2020 und 2041–2050. Concerning the bioclimatic pollution, a risk assessment considering four risk steps was realised. This was the basis for the assessment of the concerned objects of protection in respect of bioclimatic effects. The classification of the areas at risk was evaluated within the risk assessment. The bioclimatic index was used as a tool for the assessment of the risk intensity. It describes the entire impact of all climatic factors which have negative effects on living organisms. Measures for the bioclimate include mean-predicted-vote-index (PMV), heat index (HI) and wind chill (WC).

Concerning the bioclimatic impacts, a separation into hazard zones was realised: very small, moderate, and high.

31.3 Results

31.3.1 Current Climate Trends in Chemnitz – Climate Diagnosis

The analysis of the existing climate data showed the following trends:

- Annual minimum temperature increased from −18.3°C (1950s) to −13.8°C (2000s).
- Annual maximum temperature increased from 31.4°C (1950s) to 32.8°C (2000s).
- Summer days (days with a mean temperature >25°C) increased with +1.8 days/decade.
- Hot days (days with a mean temperature >30°C) increased with +0.5 days/decade.
- Frost days (Tmin < 0°C) decreased by −6.5 days/decade.
- Ice days (Tmax < 0°C) decreased by −0.2 days/decade.
- Sunshine days increased by +207 h/a (1961–1990, 2001–2008).
- Wind speeds slightly increased.
- The grass reference evapotranspiration was calculated with an increase of 526–591 mm/a, due to the higher sunshine duration and the resulting global radiation.

It is important to notice that the annual precipitation sum remained more or less constant, but the probability of heavy rains became much higher. The changes in the sunshine duration while the precipitation remains constant are reflected in the climatic water balance. A decrease of the climatic water balance in the summer months due to the higher global radiation was calculated. The results for the development of the prognosticated annual average of the air temperature in the city of Chemnitz are shown in Fig. 31.1.

31.3.2 Hazard and Risk Assessment

The next step was the assessment of the impacts of the climate prognosis results on the environmental factors in terms of their vulnerability. The impact assessment was realised using an univariate and a multivariate hazard analysis which considers the interactions between the risk factors (multifactor hazards) as well as the alleviating interactions. The considered environmental factors as well as the evaluation scale for a pressure/impact assessment are given in Fig. 31.2 and Table 31.1. For classification of the solutions, all proposed measures were evaluated for their

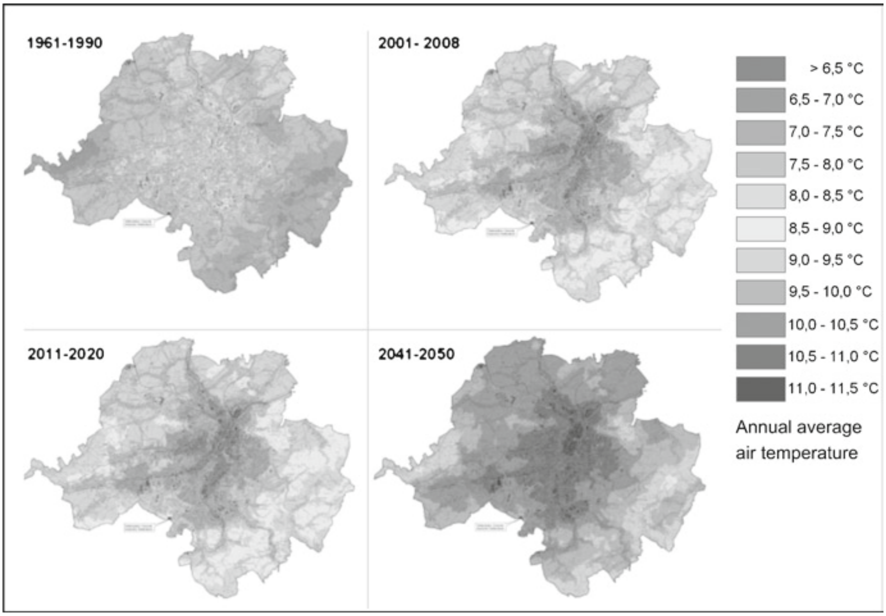

Fig. 31.1 Climate change prognosis for the city of Chemnitz – annual average air temperature

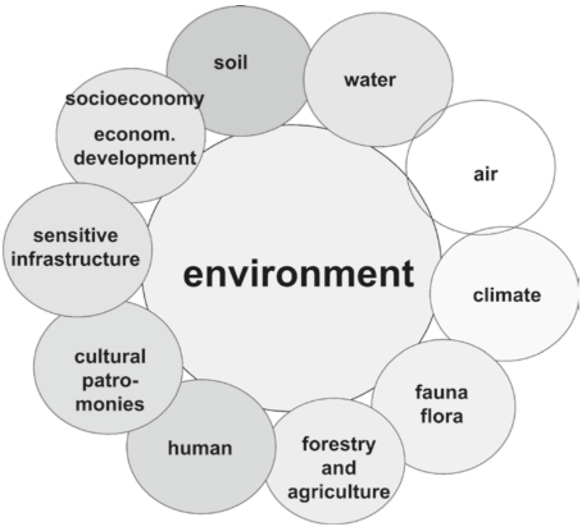

Fig. 31.2 Considered environmental factors

Table 31.1 Evaluation of risk factors

Risk	Description
Small	Risk acceptable
Significant	Decrease of risk necessary
High	Decrease of risk urgently necessary

efficiency regarding climate change mitigation as well as the practicability to be realised by the inhabitants, especially in the case of personal protection measures. The measures were prioritisied with the main focus on human health. Chemnitz's inhabitants average age is 47 years. This is due to crucial fluctuations of the young generation after the reunification of Germany and the breakdown of the economy. In this regard, the older generation is especially affected by the impacts of the climate change in Chemnitz.

The risk assessment of the concerned objects of protection was carried out for:

- Hospitals and old people's care homes.
- Schools and child care centres.
- Ecosystems: landscape conservation areas, nature protection areas, FFH-areas, water dependent ecosystems, hydro soils, forests, green areas and tree/tree groups.
- Wetlands and hydro soils.
- Cold air streams, cold air sinks.

The areas affected by climate change have been visualised using the climate prognosis data together with the location of the concerned objects of protection. This visualisation is the basis for the risk assessment and concernment analysis of the relevant objects of protection.

For the identified risk factors, the occurrence probability and risks for the individual protected recourses were evaluated within the risk analysis. As a result of the risk analysis, the risk factors could be described in the risk groups mentioned in Table 31.1. The following factors are identified as main risks:

- Climatic extreme conditions, especially heavy rains, hail storms, strong winds.
- The generally increasing average of temperature.
- Change of the water balance and impacts on the flora and fauna resulting from the declined groundwater discharge.
- Increase of UV-radiation (radiation damages).
- Increase of fire risks (increasing of temperature, soil desiccation).
- Change of soil component balance and the resulting mobilisation of bonded pollutants, which means a risk of pollutant release (humus decomposition, transport with wastewater, nitrate elutriation).
- Increase in the population of weeds and/or parasites by extension of the growing season, and warmer winters.

Figure 31.3 shows one example of the visualisation of the vulnerability assessment for human health. The figure shows the bioclimatic risk versus the location of hospitals and care homes for the elderly.

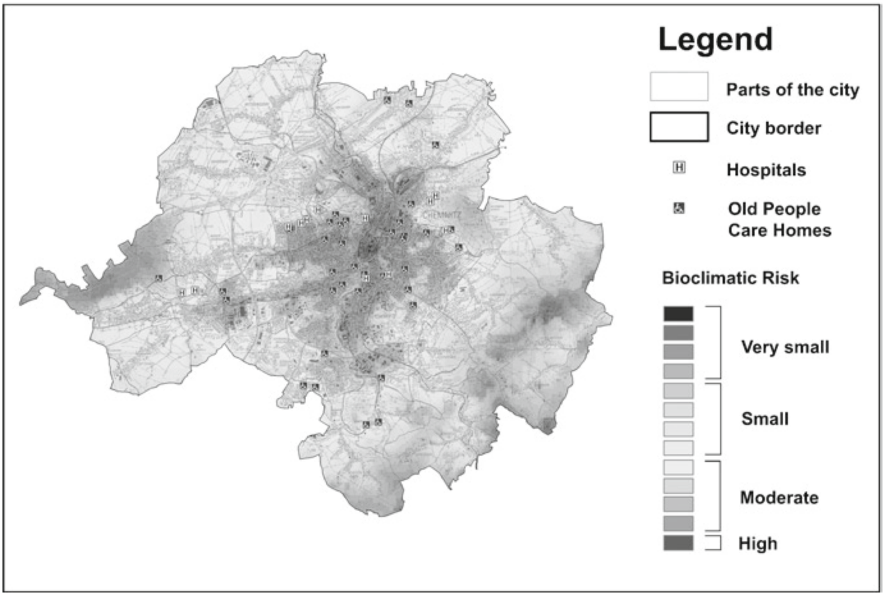

Fig. 31.3 Vulnerability assessment for humans: bioclimatic risk versus the location of hospitals and elderly care homes

31.3.3 Adaptation Measures

Adaptation to climate change means learning to live with more extreme weather events and changing weather patterns, and preparing for other changes that are unavoidable. To succeed under a changing climate, individuals, communities and city councils will all have to make significant changes in both policy and practice. The city council of Chemnitz has reached a consensus on the need for adaptation, and must ensure that decisive action is taken. Urban planning can provide solutions that will make the community less vulnerable to these risks. Green infrastructure such as gardens, parks, productive landscapes, green corridors, green roofs and walls, and blue infrastructure such as water bodies, rivers, streams, floodplains and sustainable drainage systems, play a vital role in creating climate-resilient development. For several years, the city of Chemnitz has seen strong development of greenspace as well as efforts to revitalize its rivers.

Following the risk assessment in terms of risks with the significant and high probability, adaptation measures were developed according to the measures hierarchy in Fig. 31.4. For classification of the individual solution possibilities, all measures were evaluated according to the following criteria: efficiency, acceptance, practicality, feasibility, costs, as well as a total evaluation. The purpose of developing measures was to establish qualitative and measurable climate protection measures in the fields

Fig. 31.4 Type and hierarchy of basic types of measures, evaluated for climate change adaptation measures

of policy, energy, traffic, and waste, as well as to develop measures on the personal scales, which could be realised by the citizens themselves. In the development of the adaptation measures, all departments of the city council were involved by using a questionnaire matrix to evaluate the realisation impact of the proposed measure. Most of the proposed measures are safety and organisational measures. There was a common understanding that the development of greenspace in the city plays a basic role in the development of adaptation measures to mitigate the bioclimatic pressure on inhabitants (Gill et al. 2008). Furthermore, the results show that the main fields for adaptation measures are the following:

- Public transport, especially CO_2-decreased traffic solutions.
- Traffic and parking space planning.
- Waste recycling and avoidance.
- Energy management and use of renewable energy.

31.3.4 Adaptation Strategy and City Policy

Chemnitz is focused towards innovative and ecologically sustainable measures. Considering the scope of national and international climate protection programs, Chemnitz City Council foresees the increased use of modern energy efficient technologies and renewable energy. The goal is to reach 30% power generation as well as 14% heat generation with renewable energy. The main goal is to use the innovation potential of the city and its companies to use and produce more energy efficient technologies and reduce air pollution. The following strategic guidelines were established by the city to support the adaptation strategy:

- Adaptations in the City Development Concept in terms of more greenspace.
- Climate-Protection-Scope: reduction of CO_2-emissions per inhabitant to 2.5 t/a.
- Traffic Development Concept.
- Air Protection Plan.
- The City of Chemnitz is member of the Climate Association, participating in several climate protection activities.
- Establishment of a cycling path concept.

Several steps have been implemented already, including internal and external trainings on energy saving methods for communal buildings, as well as instruction on the thrifty use of energy and water. New constructions, as well as the sanitation of old buildings will continue to be guided by energy standards and passive house construction methods. The first step was the energy assessment of communal properties and the elaboration of a priority list for building sanitation. The monthly control of the municipal heating and power consumption has existed since 1993. Public lighting was converted into energy saving lamps, including a pilot testing of LED. The city hall established funds for citizens to support the use of renewable energy (for instance, photovoltaik systems and the provision of communal roof space for private use to produce renewable energy).

Efforts to reduce greenhouse gas emissions in the public transport system have also been carried out; for instance, employees in the public service were provided bicycles by the city council. Other measures include the creation of pedestrian friendly infrastructure, the establishment of solar and gas fuel stations, and speed limits in the city traffic. Public awareness is also a crucial issue. The city council offers energy consulting for citizens, excursions to existing renewable energy facilities, information in terms of funding possibilities, as well as public awareness for sustainable development. Since 2006, several public awareness pilot projects have been initiated; i.e., on mobility ('how we will remain mobile in the future?'), on biodiversity (the Environmental Centre, agenda 21), and on climate change ('society in times of climate change and lack of resources'). The results of the discussions with citizens were included in 'City Development Concept 2020'.

The biophysical features of greenspace in urban areas, through the provision of cooler microclimates and reduction of surface water runoff, therefore offer potential to help adapt cities for climate change. However, little is known about the quantity and quality of greenspace required. The green infrastructure is 'an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations' (Benedict and McMahon, 2002, p. 12). The green infrastructure should be included at all spatial scales from urban centres to the surrounding countryside (URBED 2004). The issue of increasing the greenspace in the city of Chemnitz is a main subject in the City Development Concept, see the example in Fig. 31.5.

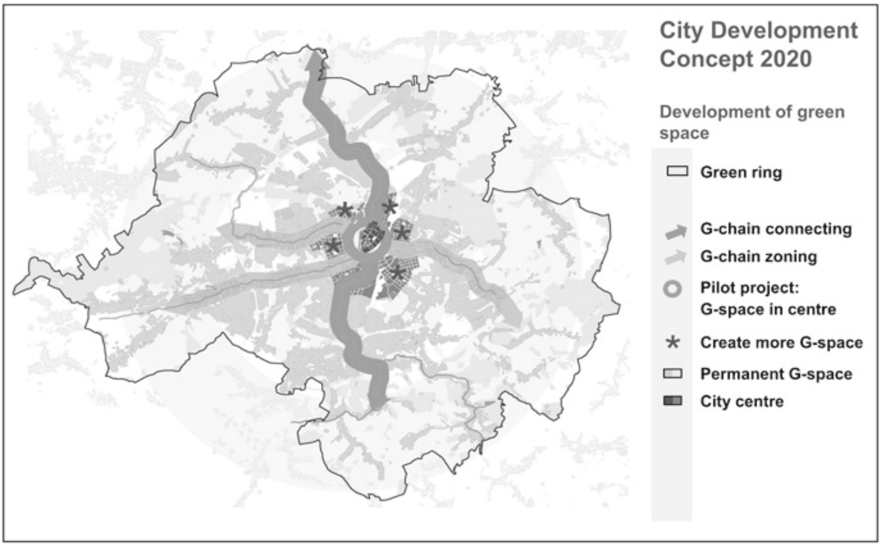

Fig. 31.5 City Development Concept 2020: example to enlarge greenspace and protect of fresh air sinks (Source: City Council of Chemnitz)

31.4 Conclusions

Climate change is already present and there is an urgent need to develop adaptive strategies. Adaptation planning is essential to bolster the resilience of communities, key resource sectors, and critical infrastructure. Adaptation to the stresses induced by climate change builds resilience. There is now also an opportunity to influence the transition from a traditional resource-based economy to an ecosystem-based economy, one that recognises and values environmental goods and services.

This project presented a pilot methodology for practical climate impact assessment on a communal scale. The results are included by decision makers in the City Development Concept and will influence city planning in terms of traffic planning, greenspace planning and the use of renewable energy sources. We thank all the contributors from the City of Chemnitz for their support.

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Chapter 32
Adaptation Strategies for the City of Cape Town: Finding the Balance Within Social-Ecological Complexity

Darryl Colenbrander, Gregg Oelofse, Anton Cartwright, Howard Gold, and Sakhile Tsotsobe

Abstract This paper describes the coastal adaptation strategies being undertaken by the City of Cape Town. The purpose of this paper is to critically examine how the city applies natural science findings within the context of influential socio-economic complexities, pressures and imperatives. These challenges are discussed as well as the methodology employed by the city to align prescriptions based on scientific investigation with the governance of one of South Africa's largest coastal cities.[1] This paper describes the challenges that the city's management has faced in developing a practical and workable solution; i.e., one that achieves a balance between socio-economic needs whilst promoting an ecosystems based management approach. Key to this discussion is spatial planning and the concept of space. This paper touches on this concept by highlighting the challenges of applying absolute boundaries (as a representation of absolute space) to demarcate static zones within the context of complex and dynamic social-ecological systems. This process is examined through the City of Cape Town's proposed Coastal Protection Zone.

Keywords Adaptation • Balance • Cape Town • Social-ecological systems

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[1]In 2007, the population of the Cape Town metropole was 3.4 million (The City of Cape Town, 2010, http://www.capetown.gov.za/en/stats/Pages/default.aspx).

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32.1 Introduction

Cape Town's municipality administers approximately 240 km of coastline, the longest stretch of sea front of any metropol in South Africa. The city's coast is also home to a diverse range of ecosystems that provide a critical support-base to a coastal population faced with vast socio-economic inequalities.[2] The importance and value of these ecosystem services is reflected in the great variety of activities associated with the coast of Cape Town. However, due to the demand and pressure on coastal ecosystems and the services they provide, coastal ecosystems are becoming increasingly transformed. The alteration of the coast from a dynamic space to an artificial one (see Figs. 32.1 and 32.2) is primarily a result of inappropriate planning and extensive development within coastal areas. As a consequence, the natural and dynamic processes of coastal ecosystems are being restricted to smaller areas. The critical threshold for them to remain functional is therefore being lost. This is measured through the decreasing ability of ecosystems to provide valuable services.

In Cape Town, a key example of the consequences of wide-scale alteration of the coastline (from hard infrastructure) is reflected in the gradual degradation of dune cordons along the coast. Dune systems, especially wind-driven systems, have historically extended far inland. Due to extensive development, these dune systems have now been restricted to narrow belts along the coast, bound on the landward side by hard infrastructure. Embryo and frontal dunes have effectively been severed from much larger systems, and due to the cross scale interdependency of such

Fig. 32.1 Muizenberg on Cape Town's False Bay in 1910. There is still space for estuary and dune dynamics (Source: Weekend Argus 2008)

[2] In 2007, approximately 230,000 people did not have access to safe drinking water (The City of Cape Town 2010).

Fig. 32.2 Muizenberg in 2008. Reflecting a drastically altered and 'fixed' landscape (Source: Weekend Argus 2008)

systems, frontal dune cordons can no longer achieve a state of dynamic equilibrium. As they require management interventions to hold them in place, these dune systems can no longer be considered natural.

Dune ecosystems provide many critical services to the city. Within the context of climate change, the most important of these services is their ability to buffer storm surges. Degrading dune systems are representative of the broader problem of the loss of space due to inappropriate development storm surges. Retaining open spaces is however critical for ecosystems to remain functional and to provide valuable services. The loss of this functionality is leading to increased vulnerability for the city. This vulnerability is manifesting in the following socio-economic issues: (1) negative impacts on coastal communities dependent upon coastal resources for their livelihoods, (2) increasing exposure of critical infrastructure to storm surge events (and the subsequent economic burden imposed on the city to protect, repair and maintain this infrastructure indefinitely) and (3) major indirect 'knock-on' impacts through a loss of aesthetic appeal and a sense of place resulting from engineered and artificial coastlines.

32.2 Adaptation Strategies: The Proposed Coastal Protection Zone (CPZ)

In response to these challenges, the city is in the process of developing a variety of coastal adaptation tools. The development of a CPZ is one such tool. The CPZ is being established to achieve two objectives. The first objective is to reinstate and conserve spaces within which coastal ecosystems are able to reach thresholds that allow them to retain their functionality. The potential for ecosystems to yield valuable services to coastal communities will therefore be increased. Notably, this includes regulatory services, such as physical protection against storm surges, as well as cultural services like retaining aesthetics, sense of place and identity. The approach of retaining open spaces also promotes the coast as a shared and common resource. Promoting equal access to the coast is critical considering South Africa's history of segregation and exclusion, and is a key requirement of the newly promulgated Integrated Coastal Management Act[3] (Glavovic 2006). The second aim of the CPZ is to prevent the many coastal problems that have resulted from inappropriate planning from recurring and increasing in the future. The city's most pressing challenge is to deal with infrastructure that is currently at risk from erosion and storm surge events.[4]

The conventional approach of dealing with infrastructure at risk from storm surges and erosion typically involves engineering and installation of hard infrastructure. However, the use of these protective measures – e.g., sea walls, groynes, and revetments – have in some cases exacerbated erosion rates. They also require substantial financial investment, not only for the initial costs of material, labor and so on, but also for ongoing maintenance expenses. As some of the vulnerable areas along the city's coastline require protection due to the presence of critical infrastructure, the city is obliged to 'hold the line' and put in place protective measures. As a consequence, the city is now effectively locked into an economic burden for an indefinite period of time. Through the establishment and regulation of the CPZ as open space, the potential for exposing the city to such burdens in the future is reduced.

32.3 Key Challenges and Opportunities

Retaining an open coastal belt that allows coastal dynamic processes to take place is only one step in the broader process of establishing the CPZ. Another key phase of this process is negotiating the various socio-economic challenges that are present. Economic imperatives are largely shaping the priorities of government strategy, which have direct implications for coastal areas. Not only is development and growth required to sustain an increasing population, but South Africa's history of inequality has also placed an added responsibility on the government to rectify the injustices of the past. In this context, development is used as a vehicle for redressing historical inequalities, a key step towards promoting social and

[3]The Integrated Coastal Management Act is a national piece of legislation that promotes an integrated approach towards sustainably managing South Africa's coastline. The Integrated Coastal Management Act became legally enforceable on the 1st December 2009.

[4]Based on the third phase of Cape Town's Sea Level Rise Risk Assessment, it is estimated that approximately 25 km^2 of land in Cape Town is at high risk from a storm surge event in the next 25 years. Approximately five billion rand worth of infrastructure is located within this area (Cartwright 2008).

economic advancement.[5] Due to the perception that coastal frontage property equates to economic wealth and gain, coastal development is being pursued to harness this economic potential.

It is envisaged that there will be positive impacts through the use of development to connect previously disadvantaged communities to the coast. There is the growing perception that the livelihoods of coastal communities will improve and that these areas are somehow more desirable places to live. This approach to poverty alleviation, however, is fuelling the existing pressures along the coast. As previously discussed, it holds the real threat of increasing the vulnerability of newly established coastal communities. But it may also ultimately lock the city into wasteful economic obligations by requiring it to protect and maintain these developments from the impact of sea level rise and dynamic coastal processes (Cartwright and Brundrit 2009). Further to this, inappropriate development planning in coastal areas increases the potential for mal-adaptation.[6] Such measures ultimately lead to the gradual deterioration of the coast through both direct and indirect impacts. The significance of this is highlighted by considering that the coast is arguably Cape Town's greatest socio-economic asset.

32.4 Absolute Boundaries and Social-Ecological Complexity

So far, this paper has touched on the complexity of social-ecological systems, and the host of challenges that need to be addressed when implementing coastal adaptation strategies such as the CPZ. Managing this complexity through the use of zones demarcated by absolute physical boundaries presents an additional challenge. To effectively regulate activities within the CPZ, some type of boundary is required to explicitly demarcate the position of the zone. This boundary, as represented by a line on the map, is an example of an absolute or physical space.

Although empirically determined absolute boundaries may cater for administrative, planning and legal language, the question arises as to the effectiveness of this boundary in terms of recognising and catering for coastal social-ecological systems, since ecosystems and coastal processes do not recognise such boundaries.[7]

The importance of this question is shown by considering that the position of these boundaries define the spatial extent of jurisdictional and management responsibilities.

[5] The approach of using development to promote economic development is formally represented by the Accelerated and Shared Growth Initiative of South Africa (ASGISA).

[6] Interventions that result in unintended negative impacts.

[7] An example of this is reflected in the difficulty of defining the position of the high water mark through the use of absolute space. In reality, the high water mark is not a 'line in the sand' but rather an area of mobility, both temporarily and spatially. Planning and legal language however tries to represent this and restrict this area to an absolute line. This disjuncture, and the dependence of other zones on the position of the high water mark is however leading to jurisdictional uncertainty and ultimately legal disputes.

Management interventions that are geared towards promoting sustainable resource management are confined to this zone. These management interventions are therefore limited as they focus only on a component of a system that functions at broader scales (Borgese 2000). As Leach and Kitchingman (2005) suggest, where mobile natural boundaries define the spatial limits of a natural resource (e.g., dune systems), administrative boundaries should only be set at the extremes of the natural variation of that resource. Similarly, it is inappropriate to employ spatially based management approaches over these resources unless they, and those environmental factors that influence them, are predictable and function within fixed spatial parameters (Leach and Kitchingman 2005).

The difficulty of determining the extent of the variation of resources, and thus where to place administrative and planning boundaries, is compounded given that dynamics of environmental processes are non-linear in nature (van den Bergh and Nijkamp 1997; Berkes et al 2003). Defining a zone through the use of absolute boundaries and applying this zone within the coastal space effectively translates into overlaying a static and socially constructed space against a space that is characterised by dynamic and multi-scale complexity (Colenbrander 2009).

Although it may be necessary to explore alternative spatial languages to 'empower' planning and management interventions to cater for social-ecological complexity, the application of absolute space is firmly entrenched within the language of spatial planning and urban design. As such, it becomes difficult and impractical to depart from the use of absolute boundaries in the management of the coastal space. In order to cater for social-ecological complexity, and to retain the language of spatial planning, the city has applied the concept of absolute space to determine the position of the CPZ, but in a more relative sense. Understanding the 'fabric' of the coastal space has been enhanced through applying a broadly consultative and multidisciplinary approach. This approach is not only critical for promoting the objectives of the CPZ, but it also elevates the degree of integration required for the management of coastal social-ecological systems.

32.5 Navigating Social-Ecological Systems: Finding the Balance

Key coastal issues that were identified in the consultation and research phase were used as informants to determine the position of the CPZ.[8] Some of these issues have already been alluded to, but in summary they include: (1) the need to promote

[8]To remain within the scope of this paper, the applied methodology will not be discussed in detail. In summary, the methodology required the collation of spatial data representative of the various informants (risk, access, dynamics, biodiversity, aesthetics/sense of place), and overlaying this data through the use of GIS to build a representative as possible overview of the coastal space. Based upon the overlay of the various key informant layers, and through determining relations and connections between these layers, the most appropriate position of the CPZ was determined.

and retain equal access to the coast and its resources, (2) the need to reduce risk to coastal communities and city infrastructure from sea level rise and storm surge events, (3) the need to protect biodiversity and coastal ecological corridors, (4) the need to conserve coastal aesthetics/sense of place, and (5) the need to reduce the impacts of coastal dynamic processes on coastal infrastructure. The end result is a variable ‘line in the sand’ that recognises and accommodates the various issues by finding a balance between scientific prescriptions and socio-economic imperatives whilst promoting an ecosystem-based management approach. Most importantly, by considering socio-economic issues, this approach has resulted in the identification of appropriate access and nodal growth points for coastal communities (see Fig. 32.3).

Although the various key informants have been listed independently to describe the process of delineating the position of the CPZ, such informants are not viewed and analysed in isolation. For example, by protecting coastal biodiversity, not only are coastal aesthetics and sense of place preserved, but the buffer potential of ecosystems is retained, which reduces risk from storm surges. The recreational and amenity value of the coast as a shared and public space is also enhanced. It is this combined functionality, and the synergies that result, which the CPZ intends to harness.

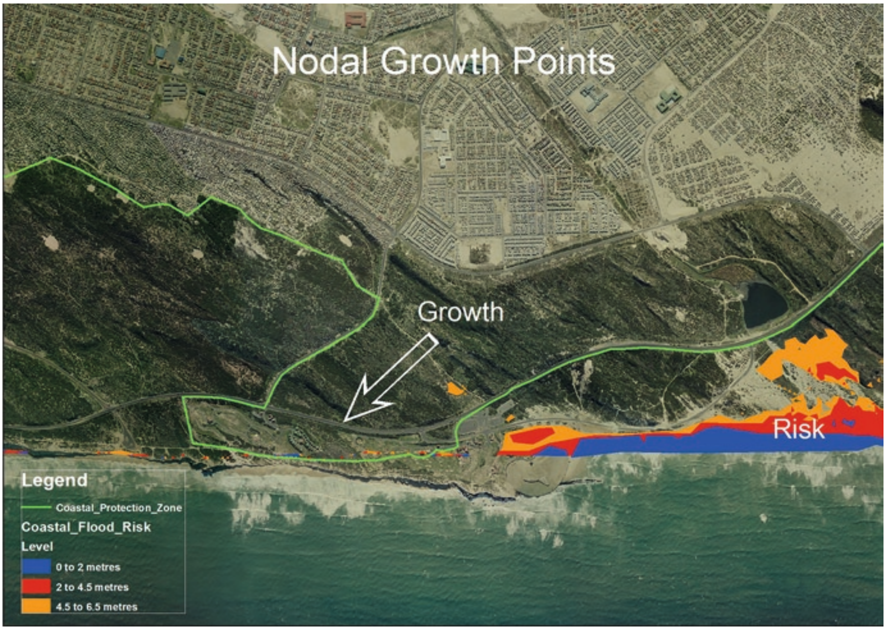

Fig. 32.3 The CPZ overlaid with the coastal inundation risk model. Appropriate areas have been identified for future nodal development

32.6 Conclusion

This paper has explored the CPZ as one of the critical coastal adaptation strategies for the City of Cape Town. Central to this approach is the need to retain a space within which remaining system dynamics and environmental fluctuations can take place. In terms of building coastal resilience, the benefit of retaining an un-altered space is twofold. First, creating a space for systems variation will reduce the potential for such fluctuations to impact social-economic systems. This will promote greater degrees of resilience to environmental perturbations (Berkes et al. 2003). Second, by maintaining this space, ecosystems are enabled to reach and retain greater degrees of functionality, which is also effective in building resilience. This case study has shown the sensitivity required to navigate through the various socio-economic and environmental imperatives contained within complex urban settings. This paper has highlighted the importance of a multi-disciplinary approach for achieving balance in the process of adaptation. This is key towards re-establishing and strengthening linkages between social and ecological systems, and is a critical step towards building a resilient coastal city.

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Chapter 33
Sharing the Lagos Megacity Experience in the Integrated Management of Sea Level Rise and Flooding

Nicholas Ozor, Oguguah M. Ngozi, and Maximus Ugwuoke

Abstract This paper describes the impacts of notable sea level rise and flooding events in Lagos megacity over the past 10 years, and the consequences of these events to humans and the ecosystem. It examines various integrated approaches adopted by successive governments in managing these impacts. Observations, literature review, personal interviews, focus group discussions, and analysis of secondary data were used to obtain relevant information from a wide range of respondents within the city. Data obtained were mainly analyzed qualitatively. Results show that the major cause of flooding was the uncontrolled expansion of impermeable surfaces due to increasing urbanization in the city. Empirical evidence of sea level rise and flooding recorded in the city include: severe coastal erosion, disruption of traffic, flooding of property, washing away of protective granite boulders, and sea level rise (e.g., of 1.5 m within 2 days in 2006). Both hard and soft measures have been employed to mitigate and adapt to these incidences, such as the construction of shoreline protection to contain sea surges and school advocacy programmes. This study recommends more aggressive capacity strengthening, advocacy programmes, international cooperation and other developmental initiatives to tackle the challenges posed by climate change in Lagos State.

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Keywords Climate change • Flooding • Integrated management • Lagos • Megacity • Sea level rise

33.1 Introduction

Flooding and sea level rise resulting from global warming are two of the greatest threats to coastal cities and low-lying areas of the world today. The most devastating impacts are regularly experienced by developing countries, especially those of Sub-Saharan Africa who, incidentally, contribute only about 4% to the greenhouse gas emissions responsible for climate change. The greater impacts in Sub-Saharan Africa can be attributed to the region's low resilience capacity as a result of low technological and institutional capacities, poverty, high population growth, increasing urbanization and poor urban planning. The Intergovernmental Panel on Climate Change (IPCC) (IPCC 2007) has projected that coasts will be exposed to increasing risks resulting from erosion, climate change and sea level rise. Natural disasters that result from, or are facilitated by, climate change can undermine decades of growth in urban regions through a single catastrophic event. Low-lying cities situated near major rivers, deltas and estuaries are especially vulnerable to sea level rise (Stern 2006). The main contributors to global sea level rise are thermal expansion of the oceans, melting of glaciers and small ice sheets, changes in the accumulation of snow, and melting of the ice sheets in Antarctica and Greenland (IPCC 2007) (see Fig. 33.1).

According to the IPCC (2007) more than two-thirds of the world's large cities are vulnerable to rising sea levels, putting millions of people at risk of extreme flooding and storms. Lagos, currently the fifth largest city in the world and Africa's second most populous city, is highly affected by sea level rise, coastal erosion, salt water intrusion, and flooding. Since economic and urban development in these areas is inevitable, and economic impacts of climate change may not only be limited to cities boundaries (Jacob et al. 2000), rising sea levels and flooding could have devastating effects on the population and economic activity in the future if not proactively checked. Bouwer et al. (2007) reported that by 2015, potential losses among the world's ten largest cities, most of which are in developing countries, are projected to increase from 22% to 88%.

Arising from the above scenarios, mitigation and adaptation remain the most popular options to manage the impacts of climate change in the world today. However, while neither adaptation nor mitigation actions alone can prevent significant climate change impacts, taken together they can significantly reduce risks. While mitigation is necessary to reduce the rate and magnitude of climate change, adaptation is essential to reduce the damages from climate change that cannot be avoided.

Since choices made today will influence the safety standards and risks of extreme flooding in the long term, it is important to study the impacts of climate change in megacities in the long term, as well as what adaptation options are available to anticipate those changes. The Stern Review (2006) noted that the effectiveness of adaptation declines as sea level rise increases. The report showed

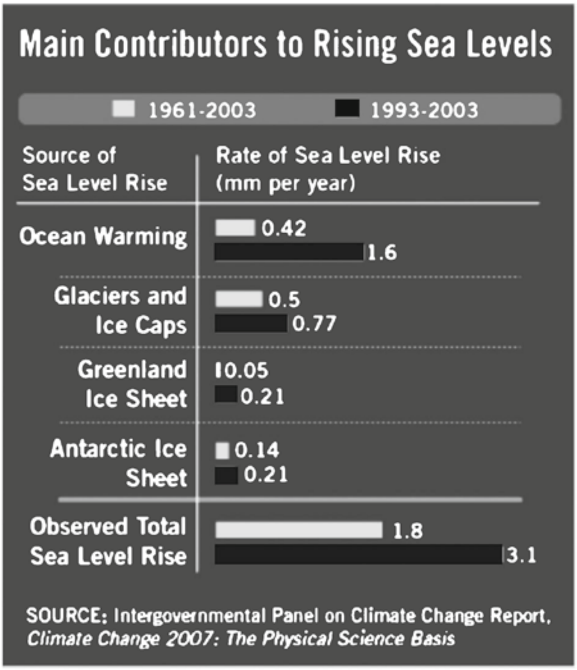

Fig. 33.1 Main contributors to global sea level rise

that for 0.5 m of sea level rise, damage costs were reduced by 80–90% with enhanced coastal protection, while the costs were only reduced by 10–70% for 1 m of sea level rise. However, for low-lying countries or regions, costs could reach almost 1% of GDP. Earlier estimates by the IPCC (2001) show the global costs of adaptation strategies in response to 1 m sea level rise amounting to US $900–$1,000 billion worldwide over a century. This would require 360,000 km of coastal defense, resulting in an overall cost of at least US $500 billion for the coming 100 years.

An earlier study by French et al. (1995) estimated that 1 m of sea level rise by 2100 – assuming no human response – would threaten 18,000 km^2 and put 3.2 million people at risk from flooding, costing US $18 billion in Nigeria[1]. Protection by hard and soft measures would reduce this risk, but would be costly. The report further maintained that protecting highly developed areas and oil infrastructure from a sea level rise of 1 m would alone cost US $600–700 million.

In order to support livelihoods and ecosystems in flood-prone coastal cities and sustain the future generations that inhabit these vulnerable areas, a more integrated management approach needs to be adopted. The robustness of such measures will determine the level of resilience of the particular megacity.

[1] These estimates are based on the 1992 population.

33.2 Purpose and Objectives

The overall objective of this study was to share the Lagos megacity experience in the integrated management of sea level rise and flooding. Specifically, the study was meant to:

1. audit notable sea level and flooding events in Lagos, the consequences to humans and ecosystems; and
2. examine the various integrated approaches adopted by successive governments in managing the impacts.

33.3 Methodology

Lagos is Africa's second most populous city, which has grown explosively from 300,000 in 1950 to an expected 18 million by the end of 2010, when it will be ranked as one of the world's ten largest cities (Mehrotra et al. 2009). The study covered the Lagos megacity, an estimated 1,000 km^2, made up of about 14 million people. The role of Lagos as the administrative capital of Nigeria until December 1991 has contributed to its rapid growth. The city is situated within latitudes 6° 23′N and 6° 41′N and longitudes 2° 42′E and 3° 42′E on the coast. The megacity is bounded in the south by the Atlantic Ocean (Bight of Benin), in the east by the Lagos Lagoon and the southwest by the Badagry Creek (Fig. 33.2). With a GDP

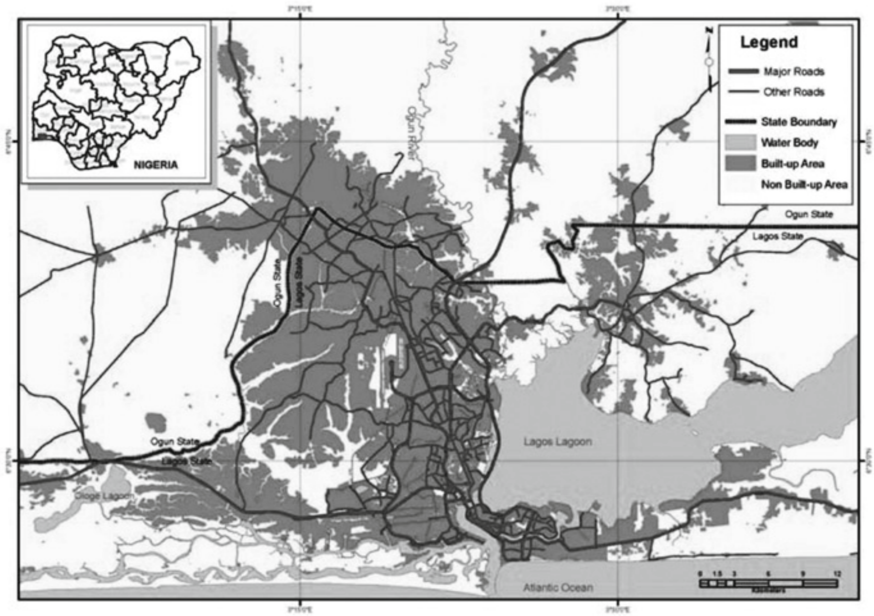

Fig. 33.2 Lagos megacity area (Mehrotra et al. 2009)

triple that of any other West African city; Lagos is the commercial and industrial hub of Nigeria. It is home to many industries and large commercial infrastructure, and has greatly benefited from Nigeria's natural resources, such as oil, natural gas, coal, fuel wood and water.

To realize the objectives of the study, in-depth literature reviews, observations, personal interviews, and focus group discussions were used to obtain relevant information from a wide range of respondents – i.e., residents, relevant institutions, private sectors, and civil society organizations within the city. Data obtained were mainly analyzed qualitatively.

33.4 Results and Discussions

33.4.1 Major Causes of Flooding in Lagos

Results show that the major cause of flooding was the uncontrolled expansion of impermeable surfaces due to increasing urbanization in the city. Other causes include runoff under high-intensity rainfall, building on floodplains, lack of storm-water drainage system, failure to maintain existing drainage systems and weak institutional capacity of the urban administration. A study of nine urban households in different parts of metropolitan Lagos have confirmed that flooding is a major problem in the city (LMDGP 2006) which appears to have worsened between 2002 and 2006. The problem is compounded by the inadequacy of the drainage network within the city, which is neither functional nor complete.

The expansion of human settlements and accompanying activities in the Lagos city is the major contributor to the flooding events in the city. Almost 70% of Lagos' population live in slums. This rapid urban growth is caused by rural poverty and urban migration. As people crowd into cities, human impacts on urban land surfaces and drainage intensify (Douglas et al. 2008). Lagos had an area of about 200 km^2 in 1960, but by the beginning of the twenty-first century the contiguously built-up area of Lagos was estimated to be about 1,140 km^2. This emerging development patterns have implications for humans and the ecosystems.

Analysis of changing land cover in the Lagos coastal area by Okude and Ademiluyi (2006) show that between 1986 and 2002, the developed land cover comprising residential, industrial, commercial, transportation and other man-made use increased from 85.44 km^2 (43.36%) to 111.89 km^2 (56.78%). Similarly, natural vegetation cover including mangrove and swamp thicket reduced from 59.24 km^2 (30.06%) to 38.31 km^2 (19.44%), while naturally occurring water bodies comprising the ocean, lagoons and streams reduced from 52.39 km^2 (26.58%) to 46.87 km^2 (23.78%) during the same period. Furthermore, between the period 1986 and 2006, wetlands, an important buffer against coastal floods, had reduced significantly in coastal Lagos. It is a common practice by the rural immigrants to satisfy their urban land needs by settling on undeveloped and unplanned areas. Such actions usually lead to the uncontrolled and unorganized development of slum communities that lack basic infrastructural facilities and contain extremely poor environmental conditions.

The institutional capacity to cope with the emerging challenges of flooding and sea level rise is not adequate. Institutional supports such as research, training and capacity building in technology and innovation against flooding are not well established in institutions. Often, the response strategies to these climate events are not planned ahead by governments, making it difficult and costly for adaptation and mitigation.

33.4.2 Evidence of Sea Level Rise and Flooding in Lagos

Earlier IPCC scenarios have been used to estimate the effects of 0.2, 0.5, 1 and 2.0 m sea level rise for Lagos. Empirical evidence of sea level rise and flooding in Lagos show that severe coastal erosions have been on the increase since 2004, resulting in acute disruption of traffic and the flooding of properties. Coastal erosion has removed over 2 km of the popular Lagos beach fronts and at times the adjacent road. It was also observed that the granite boulders constructed between 1908 and 1912 to protect the natural littoral drifts were continually washed away by the coastal surge. Bar Beach in Lagos has an annual erosion rate of 25–30 m (Mehrotra et al. 2009).

Studies have determined that between 8 and 14 m of beach-front is eroded annually along Bar Beach while an average of 2,800 m^3 of sand is eroded daily (Oniru 2009). According to Banire (2009), about half a million people in Lagos will be submerged given a rise in sea level of 1 m. He further noted that given a 2 m rise in sea level, about 1.3 million people will be submerged. This situation is catastrophic and calls for immediate action to ensure sustainable adaptation strategies in the megacity. Findings show that between the 16th and 18th of November 2006, Bar Beach was subjected to the worst storm on record for the past 10 years, as the sea level elevated to 1.5 m. During the peak of the storm, the length of the protective structure at the beach was bombarded by approximately 5,000 m^3 of sea water every 10 s (Oniru 2009).

33.4.3 Integrated Approaches in Managing Impacts

Several measures have been undertaken by successive governments in Nigeria and Lagos State Government (LSG) to effectively respond to the incidences of sea level rise and flooding in the megacity. These measures ranged from hardware to soft skills as described below.

33.4.3.1 Shoreline Protection

Statistics show that since the early 1950s, over US $250 million have been spent in the regular replenishment of sand to restore the Bar Beach areas of Victoria Island. The construction of shoreline protection embankments was approved by the government in 2005. The embankment was to cover about 1,000 m of the most severely eroded section of the beach.

Though still under construction at the time, the shoreline protection embankments are what ultimately saved Victoria Island from the November 2006 storm, which, during its peak, deposited over 1,800,000 t of sea water every hour over the length of the beach. The LSG embarked on communal dredging as well as the construction and maintenance of canals and drainage channels within the megacity. These measures have yielded tremendous results in the fight against flooding and other related events in the megacity.

33.4.3.2 Waste Management and Waste-to-Wealth Programmes

The Lagos State Government (LSG) in the past 8 years has implemented an efficient waste management programme under the Lagos State Waste Management Agency (LASWMA). In this regard, LSG has consistently improved its municipal waste collection through partnership with the private sector. The Governor of Lagos State, Babatunde Fashola, pointed out that a total of over N4 billion, or US $32 million, from the private sector has been invested directly in waste collection in the last 4 years in Lagos State. He further noted that government investment in the waste collection sector in the last 8 years is about N9 billion ($72 million) capital and N27.5 billion ($220 million) in recurrent. The investment accounted for significant improvement of about 75% efficiency in waste collection in Lagos, i.e., a significant increase from 30% in 1999 to 75% in 2007. An integrated landfill waste management facility, comprised of an engineered sanitary landfill site, material recovery plant, bio-gas and leachate collection, and a composting facility, is already in use for proper waste management in the State.

Additionally, LSG is implementing a waste-to-wealth programme through public-private partnerships, one of which has a plant that currently converts 500 t of municipal solid waste into organic fertilizer (Babatunde 2008). A nylon/plastic buy-back programme is also underway that pays youth to collect plastic trash that is recycled into pellets and intermediate raw material for other products.

33.4.3.3 Low Carbon Emission Strategies

In order to reduce the vehicular emission of greenhouse gases responsible for climate change and eventual sea level rise, the LSG inaugurated the Bus Rapid Transit System to commute passengers on fast track uninterrupted lanes. The state government also activated the Vehicle Testing Program aimed at removing unroadworthy vehicles from the road. In order to decongest the road transport system, the state government is currently dredging the waterways and constructing jetties to prepare for the expansion of water transit services across several routes in the city. Similarly, the Operation Green Lagos Project has seen many trees planted in the city. All the above strategies aim to reduce the greenhouse gas emissions from Lagos.

33.4.3.4 School Advocacy Programme and the Climate Change Club

The school advocacy programme comprising the climate change clubs is an outreach programme in which students of primary and post primary institutions in Lagos are educated on the issue of climate change and environmental management by specially trained instructors. Under these arrangements the Climate Change Club has been established in 172 primary schools and 348 post primary institutions in the state with 105 graduate instructors engaged on all aspects of environmental matters as they relate to climate change (Banire 2009).

It is impressive to note that since the launch of the school advocacy programme in 2008, the awareness level of climate change and environmental sustainability has increased tremendously. According to a survey conducted by the State Ministry of the Environment, the level of awareness on climate change rose from 15% before the introduction of the programme to 85% after the launch (Banire 2009).

33.5 Conclusion and Recommendations

This paper shared Lagos' experience in the integrated management of sea level rise and flooding. It identified the major causes and consequences of sea level rise and flooding in the megacity – namely, the removal of about 2 km of Bar Beach front since 2004 by coastal surges. The paper also examined the measures already taken by governments in managing the situation. The integrated approach, comprising of both hardware and soft skills include: the construction of shoreline protection, integrated waste management programmes, low carbon emission strategies, and the school advocacy programme among others. These measures have gone a long way towards improving the city to date.

Based on the key findings from this study, it is recommended that more advocacy and awareness programmes on climate change be mounted in Lagos in order to sustain the momentum of the already existing programmes. The Lagos State House of Assembly should endeavour to pass the climate change bill. The state should embark on strengthening its personnel capacity, equipping them with the necessary skills to tackle the growing challenges of global climate change. Lagos State Government should also maintain its prominence in the consortium of cities under threat by coastal erosion and flooding in order to harness opportunities for international cooperation and assistance.

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Chapter 34
Community-Based Vulnerability Assessment: Semarang, Indonesia

John Taylor

Abstract This paper documents the process and results of a community based climate change vulnerability assessment carried out in the Indonesian coastal city of Semarang between October and November 2009. It considers which groups are most vulnerable to extreme climate events and where they are located within the city. It characterizes the nature of their vulnerability, as well as the existing adaptive capacities that poor urban communities in Semarang have developed. This paper suggests that resilience and adaptation strategies should build off existing adaptive capacity and strategies already developed by urban poor communities, proposing a few ideas for further consideration and exploration.

Keywords Adaptation • Climate change • Indonesian cities • Resilience • Vulnerability

34.1 Introduction

The following paper presents the results of a community based vulnerability assessment, completed between October and December 2010 for the Rockefeller Foundation's Asian Cities Climate Change Resilience Network and Mercy Corps Indonesia. The objective of the study was to determine which groups are the most vulnerable to climate change within the city of Semarang, Indonesia. Existing adaptive capacities of urban poor communities were also identified. Such findings can help to direct climate change preparedness policy away from simple 'brick and mortar' strategies to institutional and policy oriented responses that build upon existing capacities.

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The community based vulnerability assessment sought to understand who is affected by extreme climate events, where they live, and how they are affected. By determining these three factors, we can better target those who are most vulnerable by addressing their specific needs. This paper begins by characterizing the groups of people and the places most vulnerable to climate change within Semarang. This is followed by a discussion of the various factors contributing to vulnerability. Various adaptations that were identified in the study sites are then described in detail. An analysis is performed to learn what lessons can be gained from these adaptations, identifying constraints, opportunities and factors that may determine the success of adaptation strategies. Finally, a list of ideas is elaborated about potential ways in which to strengthen resilience in both cities.

34.2 Characterization of Vulnerability in Semarang

Semarang is a large port city with a population of approximately 1.4 million. The city's economic base is tied to its strategic position as Central Java's principal gateway for trade. As a result, it has grown dramatically, attracting migrants throughout Java and beyond. The climate hazards it suffers from – flooding, sea-water incursion, subsidence, landslides, and cyclones – are related to its low-lying coastal position. Four *Kelurahans*, or neighborhoods, made up the case study sites examined in this paper: Tandang, Sukorejo, Mangunharjo and Kemijen.

34.2.1 Types of Areas

Low lying coastal lands exposed to flooding and sea-level rise: Low lying areas are vulnerable to flooding from rising tides that happen yearly, the gradual rise of sea levels, subsidence or sinking ground level, as well as flooding from rains. In Semarang, low lying coastal areas are occupied by residential and industrial activities, both of which are adversely affected by these phenomena.

River basin settlements exposed to flooding: Downstream communities and those on riverbanks are particularly affected by flooding during the rainy season. This situation is particularly hazardous in steep areas where flash flooding can catch communities off guard, devastating their homes and livelihoods. Water can also deposit sewage, domestic waste and seawater in areas that are usually dry. In the absence of adequate drainage, this water and waste can stagnate and cause additional health problems.

Areas exposed to land movements and landslides: Communities on hillsides surrounding the city can be exposed to erratic and destructive land movements. The Sukorejo area suffers from land movement during the rainy season. This can destroy infrastructure, houses and other types of property. Communities in these areas have to rebuild both homes and community services every year due to the damage caused by land movements.

34.2.2 Groups of People

Families moved in government relocation programs: Families who have been moved from one settlement to another by government relocation programs are particularly vulnerable given sudden changes to their lives and the difficulty of restarting life in new surroundings. A number of people in the areas of Tandang and Sukorejo have been relocated due to the construction of a toll road. Without access to jobs, and having been uprooted from their previous communities, these groups often suffer prolonged hardship in starting their lives anew.

Poor urban residents: Poor urban residents are considered vulnerable since they often occupy areas of the city that are at high exposure to risk. Seeking areas that are inexpensive, easy to occupy and close to employment opportunities, the urban poor are often forced to settle in locations that are precarious; e.g., riverbanks, steep hillsides, areas along train tracks, abandoned land or rubbish dumps.

Those in areas that will be occupied by large infrastructure projects: Given the continued growth of cities, there is constant demand for major infrastructure projects to open new areas for development. Whether it is for large pumping facilities (Kemijen) or toll roads (various communities in Semarang), cities are continually developing new plots of land. Those who have settled in these areas often have no legal tenure and little recognition by the state. These communities are therefore vulnerable to relocation without just compensation.

Those dependent on industries in low lying areas: Communities that are dependent on specific industries, such as the port or fishing, are particularly vulnerable since they rely heavily on jobs coming from that single sector. Given a sudden change in the conditions of that market, these communities have few other economic opportunities outside of those activities provided by their proximity to the sea.

New arrivals/urban poor migrants: New arrivals to the city from the interior or other coastal areas are particularly vulnerable since they have few housing opportunities available to them other than in areas in the most vulnerable parts of the city.

Female-headed families: Female-headed families (widowed woman or single parent households) often carry the heavy burden of supporting children and/or the elderly. This increases their vulnerability to sudden changes in their surroundings and adverse weather conditions.

34.3 Vulnerability to Climate Change in Urban Areas

There are several lessons we can learn by examining the communities within the case study areas of Semarang. Below, seven lessons are listed.

34.3.1 Vulnerability Is Closely Linked with Poverty

In Semarang, the most vulnerable groups are the urban poor. Without any alternatives, poor populations tend to settle in locations previously uninhabited due to their exposure to risk. The effort and costs of maintaining their existence in these areas is often so high that they are effectively tied to living there. This perpetuates their precarious situation and limits their opportunity to move to safer areas – in effect, a poverty trap.

34.3.2 Relocation of Communities Can Be Potentially Devastating (or Not)

Since sea-level rise is making coastline areas increasingly uninhabitable, an obvious solution is to move populations to safer areas inland. This can be devastating for urban communities, but not necessarily so. As mentioned above, communities located in low-lying areas can be exposed to a triple or quadruple threat from rising tides, sea-level rise, flooding and land subsidence. They are also very poor and often dependent on jobs in the area. Relocating a community without any thought to their future well-being can leave them in a similar or worse situation with respect to their vulnerability. However, relocation *can* significantly improve the quality of life of communities by reducing their exposure to risk and giving them the ability to incrementally invest in their homes and community. For relocated urban communities in Sukorejo, the discontinuity of government support compounded by physical isolation and hazardous conditions has rendered their living conditions precarious; the community has remained dependent and helpless for years. In Tandang, however, despite having received similarly meager compensation, stable relocation conditions have enabled them to consolidate their situation over the course of 20 years.

34.3.3 State Support Can Play a Large Role in Reducing or Increasing Vulnerability

Given adequate assistance, vulnerable urban communities can build resilience and reduce their socio-economic, physical and environmental vulnerability. This depends to a large extent on the degree to which the government is able to assist in consolidating their communities. Given an active and constructive engagement between local government and local communities, physical and economic conditions can improve significantly, thereby reducing vulnerability. In several cases, local government investment in vulnerable areas has allowed communities to bolster their resilience. Of course, continued improvement depends upon other factors as well, such as favorable economic conditions, characteristics of the local culture, and leadership. The case of Tandang demonstrates how continued partnerships between community and government can lead to the positive evolution of settlements. The case of Sukorejo, however, demonstrates that when a community develops dependency on government, or complete disengagement with it, their vulnerability can persist or increase.

34.3.4 Vulnerability Is Compounded by a Lack of Knowledge and Access to Resources

In the same way that humans require nutrition in order to maintain resistance and strength, urban communities require information to maintain their resilience and adaptive capacity. The adaptive capacity of urban poor communities is severely limited without access to education and job skills, contact with government departments and institutions, and access to legal information. Negotiation, for example, requires information that can help people evaluate options and make appropriate decisions. Without knowledge of previous communities' experiences with relocation, vulnerable communities are unable to negotiate fair deals. As it stands, these communities are caught between the fear of losing their current jobs, not knowing what type of future awaits them, and the insecurity of empty government promises.

34.3.5 The Market Is the Ultimate Determinant of Vulnerable Conditions

In almost all cases, vulnerability and risk are distributed according to the land market (the poor can only access land that is exposed to hazards), and the job market (most jobs available to the poor expose them to hazards or prevent them from accumulating enough capital to escape poverty). If disaster or extreme weather phenomena hit, the poor are the most likely to be affected as they have little financial capacity to rebound. At the moment, vulnerability and risk (economic and environmental) fall heavily upon the poor who are unable to leave their current communities over fear of losing access to jobs. To persuade these communities to relocate, government would have to guarantee access to better conditions (housing, jobs and legal tenure) in other areas. One of the only ways in which this cycle can be broken is through the intervention of government.

34.3.6 Women, Children and the Elderly Are Particularly Vulnerable to Severe Climate Events

There are noticeable differences in the ways that women and men experience vulnerability. Many of the reasons are cultural and can be attributed to the different roles that women are expected to have with respect to work, education and family. Having been deprived of a complete education and expected to maintain household duties, women, particularly in urban poor communities, are often those least able to avoid the impacts of climate events. Women may also lack the knowledge necessary in order to prepare for such events. If, for example, they are unable to work or study, women may not have the economic means or the information necessary to cope with change.

34.4 Existing Adaptive Capacity in Semarang

In this section, we look at existing adaptation measures that communities and individuals have developed. These adaptation strategies have been observed in the communities studied during the community based vulnerability assessment.

Data collection and modernization: The Kelurahan government of Tandang has developed detailed maps of their territory, roads, and community assets, as well as risk maps that locate areas and types of risk. The maps provide vital information to identify areas that are the most vulnerable, which is useful for developing accurate early warning systems.

Developing alternative access to basic services: In the absence of local government provision of water, many communities have had to find alternative sources. In the community of Kemijen, the lack of services provided by the local water utility has meant that a large number of families have had to buy water from private providers. In doing so, they are adapting to local constraints; however, this is often comes at a costly price.

Savings groups: Community savings groups (*Arisans*) are made up of neighbors and friends who come together weekly to collect small amounts of money. The groups are organized based on the saving capacity of each family – the payout also varies depending on the amount contributed. This adaptation leverages the collective savings capacity of neighbors, and allows a degree of financial freedom for beneficiaries to invest in larger than usual investments.

Switching from farming to the processing of fish/shrimp: In 2000, the price of shrimp sharply declined. This affected sales made by the community of Mangunharjo. In response, the community decided to process shrimp into different types of product, such as krupuk, a popular Indonesian snack. By setting up industry within homes and diversifying their products, certain communities have been able to survive the decline of shrimp prices and can now earn more money from processed products.

Raising community capital to leverage government support: Joint investment projects, in which the local community raises capital and the local government adds funds, have improved Kelurahan conditions in Tandang. This is especially true for infrastructure projects. The key element of such a scheme is the community's ability to leverage government funds with their own income. Financial partnership with government, then, is a powerful adaptation strategy.

Political engagement and local community organization: Productive engagement between local communities and city government takes leadership and willingness on behalf of both government and community members. Converting social capital into political capital is an effective adaptation that may gain communities allies and access to projects and resources.

34.5 Lessons Learned

The factors listed below offer some insight into what determines the success and viability of certain adaptation strategies; that is, what characteristics have made certain strategies possible, and for what reasons have communities chosen these over other options.

Inexpensive and work with available materials: Adaptation strategies can take time to develop through the consistent application of resources and services. For the urban poor, however, these resources and services are often scarce. This means that solutions must often come from inexpensive or free sources. On the material side, examples include scavenged housing materials. Community savings groups that require very small monetary contributions are also attractive options.

Accessible in times of need: Adaptation strategies must be accessible when they are needed most; that is, in times of distress. In order to raise capital to recover from a flood, say, a family may sell their television, motorbike or other fungible assets, rather than go through the bureaucratic process of filling out applications. Generally, people in the city want quick access to resources. This is a very important characteristic of adaptation strategies that work.

Adaptation to severe climate events must work together with other strategies: The needs of the urban poor require them to have very practical outlooks. The adaptation strategies that are most successful for them, then, are those that can be combined with other strategies connected to their concerns about health, housing, education and jobs. If certain measures can make their lives safer but also provide them with better income, say, then it is these measures that they are likely to pursue.

Leveraging government support leads to better results: When communities are able to work together with local and city government (and vice versa), adaptation strategies are often most successful. For example, community investments when matched or leveraged with government investments were able to make significant and lasting impacts on conditions within Kelurahans.

More access to information can lead to better outcomes: Vulnerable communities have to constantly evaluate their situation, be it economic, housing or health. Adaptation strategies that can help them to have more access to information and thereby make better decisions about their situation will lead them to better outcomes. Urban poor communities are usually isolated and so successful adaptation strategies seem to increase access to information.

34.6 Ideas to Strengthen Adaptive Capacity

The strategies and projects outlined below offer a few possible ideas of how to strengthen adaptive capacity in Semarang. Lessons can be easily learned and transferred from these cases since (1) they have already proved workable in parts of the city and (2) they would be more easily introduced from communities and groups that come from similar contexts rather than brought in from outside agents.

Data collection: In the case of certain hitherto unrecognized or undocumented communities, a community level census and survey would help to document the exact needs of residents and help articulate them in a way that is most useful for local government support.

Subsidies: Given the precarious economic situation faced by poor urban communities, certain services are simply out of reach. Government could assist by subsidizing access to these services. Subsidies for education and water would also help bolster resilience and reduce vulnerability in many urban poor communities.

Supporting community networks: Many urban poor communities live in isolated existence. This often makes them unaware that their experiences are similar to those of other urban poor communities. Exchange between these communities should be encouraged to help form social networks, the sharing of information and learning. Urban populations who are to be relocated could gain useful knowledge for negotiating relocation conditions and compensation with local government or land developers.

Kelurahan vulnerability index: A number of communities have been identified as possessing qualities that make them highly vulnerable to climate change. Through progressive investment in projects and improvements, some of these qualities can be reduced over time. A database can monitor progress in time and space, allowing Kelurahans to continually gauge their own vulnerability.

Detailed maps for local government use: The Kelurahan government of Tandang has demonstrated a useful disaster preparedness and response measure. By keeping detailed maps at hand that identify assets, characterisitics of populations and specific hazards within communities, they are better able to prepare for climate related disasters; for example, by setting up early warning systems. Access to information in a clear and accessible format is essential to reduce vulnerability and strengthen resilience. Maps and a community database can help provide this.

Broad-based coalitions to deal with climate change: While climate change is a particular concern for urban poor populations, many other constituencies are potentially affected. This calls for the organisation of large coalitions that can push for government response and create greater visibility for the issue.

34.7 Conclusion

Semarang's community based vulnerability assessment has helped to demonstrate that while urban communities are vulnerable to climate change – particularly urban poor communities – they have developed adaptive measures to confront these challenges. However, greater institutional support and resources are needed to turn short-term solutions into more comprehensive and long-term strategies. Resilience planning should aim to strengthen existing community-level adaptive capacity and focus on interventions that support the most vulnerable groups within the population.

Chapter 35
Research News for Climate Compliant Cities: The Case of Ho Chi Minh City, Vietnam

Frank Schwartze, Andreas Gravert, Ronald Eckert, Ulrike Schinkel, and Ralf Kersten

Abstract This paper presents intermediate results of the research project 'Integrative Urban and Environmental Planning for the Adaptation of Ho Chi Minh City (HCMC) to Climate Change', which is part of the research initiative 'Sustainable Development of the Megacities of Tomorrow' of the German Ministry of Education and Research (BMBF). The overall objective of the research project is to develop and incorporate climate change adaptation strategies into urban decision-making and planning processes, which will increase resiliency to climate-related physical and social vulnerabilities for the urban system of HCMC. This paper argues that inclusive and effective urban planning is essential for climate adapted and energy efficient urban development. A dual strategy of top down and bottom up approaches is emphasized. It aims to improve local climate change response capacity and facilitate the integration of guidelines into the planning levels of the Vietnamese legal framework. The concept of 'three-level guidelines' is presented, providing a framework for climate change response on the conurbation, neighbourhood and building level. A Toolkit of Adaptation Measures and a Design Catalogue for the Promotion of Energy-Efficient and Climate Adapted Buildings as well as planning studies and a Community Based Adaptation Scheme are developed as part of the bottom-up activities.

Keywords Adaptation • Climate change • Ho Chi Minh City • Urban planning • Vietnam

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35.1 Research for Climate Compliant Cities: The Case of the Ho Chi Minh City Metropolitan Region

As an emerging coastal economy, Vietnam will be extremely vulnerable to climate change impacts in the future because of its topography. Most of the population and economic activities are concentrated in the low elevation coastal zone. This area, situated less than 10 m above sea level, covers the large part of Vietnam's agricultural and urbanized land and is home to more than 74% of the population (Carew-Reid 2008). With a predicted sea level rise (SLR) of 1 m, around 5%of the overall land surface and around 11% of urbanized areas will become inundated, affecting almost six million inhabitants (Carew-Reid 2008; World Bank 2007).

Since 1986, when the Doi Moi reforms were introduced, Vietnam has developed from a centrally planned system marked by hyperinflation and supply shortfalls to a 'socialist-oriented market economy' featuring one of the highest economic growth rates in Asia. The HCMC Metropolitan Region is the main growth hub of Vietnam and the biggest beneficiary of the transition attracting more than 50% of Vietnam's foreign direct investments (FDI) and showing annual economic growth rates constantly exceeding 10% (SIURP/MoC 2007). A recent economic study revealed that Ho Chi Minh City and Hanoi, the two major urban centres of Vietnam, will become the world's top two agglomerations based on projected average real GDP growth in 2008–2025 (PricewaterhouseCoopers 2009).

The population of HCMC is growing rapidly. The settlement area has more than doubled since the introduction of the Doi Moi reforms, with an estimated population of 7.1 million official inhabitants in 2008, plus around 2 million unregistered migrants. Population scenarios estimate a population of around 9–11 million official inhabitants by 2025 (UPI and Nikken Sekkei 2007). Growing beyond administrative boundaries, the agglomeration of HCMC is certainly becoming a mega-urban region with more than 20 million inhabitants by 2025 in HCMC and the 6 neighbouring provinces (SIURP/MoC 2007).

With rapid urban expansion taking place in the region, it is considered to be one of the most vulnerable areas in the world in terms of population exposed to climate change impacts (Warner et al. 2009; ADB 2008). Located on the north-eastern edge of the Mekong Delta and approximately 50 km inbound from the South China Sea, HCMC is built mostly on low-lying and marshy land. Over 60% of the administrative urban area is situated at no more than 1.5 m above sea level (Ho Long Phi 2007). A widespread network of rivers and canals with a combined length of almost 8,000 km covers 16% of the city area (Nguyen Minh Hoa and Son Than Tung 2007). Given the predicted SLR of approximately 1 m by the end of this century, almost half of HCMC's administrative area will become inundated, endangering more than 660,000 inhabitants (Carew-Reid 2008).

Urban development patterns, such as the sealing of land or the pollution of the sewer system, add to these climate change effects. Already large parts of the city are frequently flooded due to infiltration of tides and heavy rain events. Soil erosion and flooding regularly damage houses and infrastructures, and saline intrusion caused by rising sea levels threatens water supply and agriculture. Environmental migration (IOM 2007) from the Mekong Delta which is home to 18 million people is another consequence of climate change already under way (Warner et al. 2009).

HCMC will also have to cope with higher temperatures and the urban heat island effect (UHI). Densely built urban districts can become overheated due to several factors; e.g., a lack of vegetation, lack of surface water and evaporation areas, reduced air convection, changes in the thermal properties of surface materials, and heat generated by air conditioning, transportation or industry. In the inner city of HCMC, the UHI effect is clearly noticeable with temperatures averaging 10° higher than that of the surrounding areas. With a projected rise in temperatures in South Vietnam of 1–2°C by 2050 (Booth et al. 1999), health and comfort of urban living is likely to deteriorate while demand for cooling will increase.

35.1.1 The Project Approach

The basic motivation of this research project is to increase the response capacity of HCMC by strengthening the urban planning system and mainstreaming climate change action. Response capacity in this context is broadly understood as the ability of a system to manage both the adaptation to impacts of climate change (adaptive capacity) and the reduction of greenhouse gas emissions (mitigative capacity) (Tompkins and Adger 2005; Yohe 2001). It is argued that inclusive and effective urban planning holds the key for climate adapted and energy efficient urban development, since it will combine long term thinking and short term action. Moreover, urban planning seeks to balance the interests of different stakeholders and to define the relationship between city and environment. This relationship is at the core of climate change response, since HCMC's current and future environmental threats are mostly the result of both urban development and climatic change.

The project assesses risks and vulnerabilities deriving from environmental change in HCMC and develops mitigation and adaptation measures. It aims to incorporate both vulnerability assessment and response measures into urban decision-making and planning processes beyond the project period. Two major topics constitute the project structure: The first, Action Field 1 'Urban Environment', evaluates the local impacts of climate change as well as their spatial manifestations (for a detailed description of the Urban Environmental Planning Information System and the Adaptive Land Use Planning within Action Field 1, see Storch et al. 2009). The focus of this paper is on the second, Action field 2 'Urban Development', which develops strategies for adapting the built environment and future urban development to environmental challenges.

35.2 Mainstreaming Climate Change Response into the Planning System

In contrast to the general notion that awareness of climate change in developing countries is low and in need of attention, decision-makers and planners within HCMC and at the national level have revealed a high degree of awareness on the subject. This is not only due to the increased global recognition reflected in the agendas of international institutions, which are trickling down from the global to the national level, and most recently to the local level. Here, every province is now obliged to set up an Action Plan to Respond to Climate Change. Pressure on the city's authorities to act has also resulted from increasingly frequent and severe flooding, which has brought high public awareness and media attention. Accordingly, reducing vulnerability to climate change has become an urgent issue on the agenda of Vietnamese urban and environmental planning institutions. The implementation of measures to adapt the city, however, is still limited. This gap between awareness and action leads to the conclusion that HCMC faces not only a lack of reliable information but also a lack of effective planning instruments and limitations in its institutional setting.

35.2.1 Integration Approach to Urban Planning

In order to mainstream climate change action into the urban planning system and to improve response capacity, the project applies a dual strategy. On the one hand, a formal top-down oriented approach is being followed where it is worked towards the readjustment of the legal framework that frames lower order decisions and decision making processes. On the other hand, a bottom-up strategy is adopted, which aims to improve local climate change response capacity in the urban planning and construction sector by applying a diverse set of measures.

The top-down oriented regulatory approach is applied firstly in response to a lack of regulation regarding environmental policy and climate change concerns in the planning sector. In order to fill this gap, Guidelines for Resource Efficient and Climate Change Adapted Urban Structures are being developed. Based on an analysis of the formal planning system, opportunities for their legal integration are identified and the implementation of such guidelines is pursued. The development and implementation of guidelines is a great chance to mainstream climate change response across levels and localities. It does not ensure, however, their effective application on the local level. In fact, the fundamental problem of the Vietnamese planning system seems to lie not in the lack of formal regulations, but rather in the correct application and implementation of these regulations. With this in mind, the top-down approach is complemented by a bottom-up strategy. The latter implies a diverse approach including the implementation of a Community Based Adaptation Scheme, the elaboration of a Planning Study for Climate Change

Adapted and Energy Efficient Neighbourhoods, and the preparation of a Toolkit of Adaptation Measures to Climate Change.

The final objective of the project is to link top-down and bottom-up processes. By doing so, conditions can be met which allow for the creation of an adaptive 'learning system' that integrate conflicting ideas and approaches.

35.2.2 Top-Down Approach: Implementation of Urban Planning and Design Guidelines

Because adaptation requires a multi-spatial approach, the research project has adopted the idea of developing appropriate Guidelines for Resource Efficient and Climate Change Adapted Urban Structures on three spatial levels: conurbation (level 1), the neighbourhood (level 2), and the building level (level 3).

At the overall level of the city, the level 1 guidelines will mainly be related to environmental vulnerabilities and general strategic development. They must correlate with the zoning categories of the statutory urban development plans and will act as a blueprint for a readjusted Urban Construction Master Plan and the Regional Development Plan – both established legal documents in the planning framework of Vietnam.

The level 2 guidelines for future development of both new and existing neighbourhoods must, first, respond to the impacts of climate change, the shortcomings of the existing sewerage system and the preservation of the natural environment and urban climate at the neighbourhood level. These guidelines should be implemented in zoning and detailed plans in relation to urban renewal projects and urban expansion projects.

With the level 3 guidelines at the level of single buildings, specific considerations have to be given to aspects like durability, ventilation and openness, thermal insulation, disaster prevention and energy saving. The demand for climate conscious housing typologies in HCMC is already immense and will drastically increase in the near future. Based on a number of prototypical houses for several target groups, different elements and measures for energy efficiency and climate change adaptation have to be developed and integrated into the building code, which regulates construction activities on the building level.

In the top-down orientated political system of Vietnam, the implementation of regulations for adapted planning and building into the national laws and decrees is essential. While at the building level certain regulations are already effectively implemented via the building code, regulations are lacking for the levels of regional, general, zoning and detailed planning. Even HCMC's main planning institutions formulated the demand for a set-up or the extension of appropriate planning standards in this context. Here, the construction law and the newly set-up urban planning law are among the most important statutory documents that need to be linked with the mainstreaming of environmental policy and climate change response (Fig. 35.1).

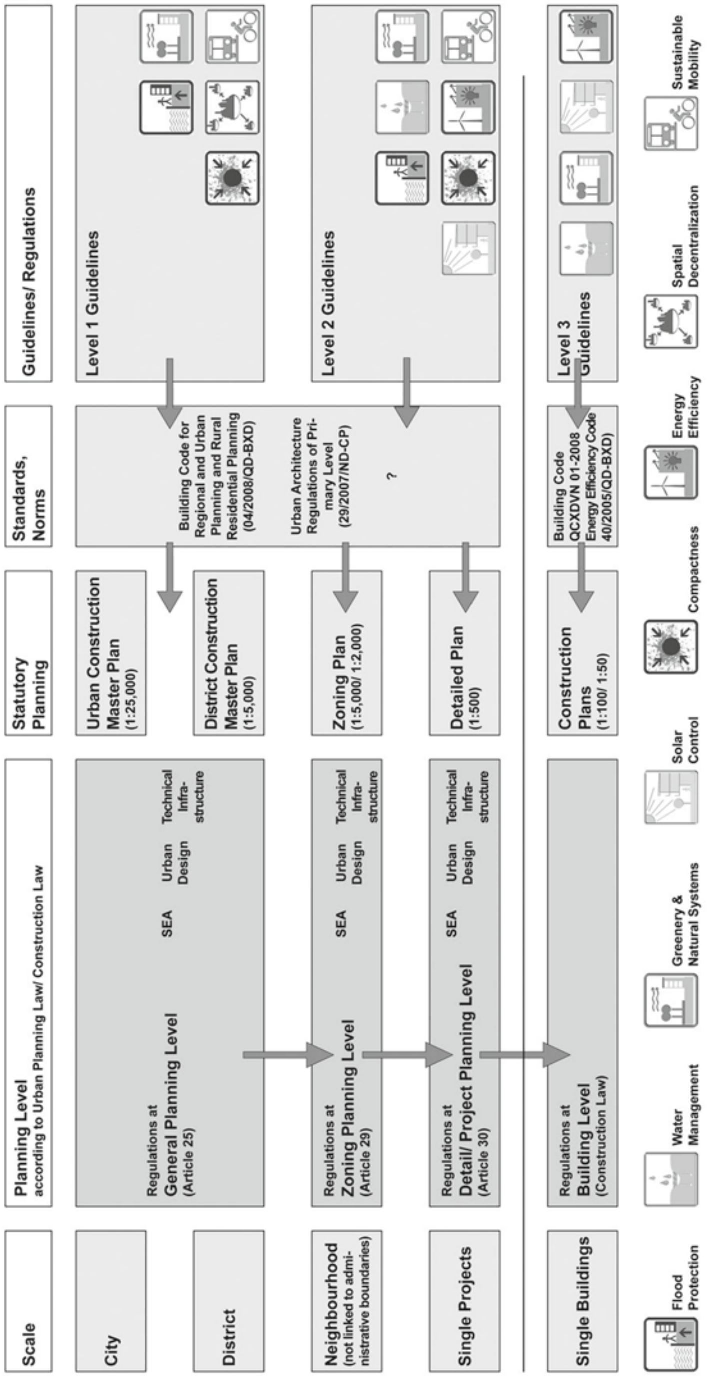

Fig. 35.1 Approach for the legal implementation of the Guidelines for Resource Efficient and Climate Change Adapted Urban Structures

35.2.3 Bottom-Up Approach: Dissemination of Knowledge and Application of Best-Practice

As mentioned above, the implementation of guidelines into the legal planning procedures does not ensure their effective spatially inclusive application. Thus, the strengthening of acceptance for, and knowledge of, adaptation measures among those who apply the top-down policies and directives on the local level is crucial. Bottom-up strategies are therefore applied, targeting at local decision makers, developers and own-home builders, architects and planners as well as affected communities.

The Toolkit of Adaptation Measures to Climate Change is an extensive catalogue, which provides a broad range of potential options for the adaptation of HCMC. Adaptation practices can be differentiated along several dimensions: by spatial scale, by type of action, by actor, by climatic zone, or by sector (Adger et al. 2007). The latter served to systematize the following set of spatial measures to effectively respond to the thematic sectors of flooding, climate, energy and transport. However, as Adger et al. argue, all measures are subject to a multi-dimensional implementation on different scales, by different actors and with different types of action. The toolkit aims at the empowerment of local decision makers and other actors concerned with planning and building (Fig. 35.2).

The Planning Study for Climate Change and Energy Efficient Neighbourhoods will serve as a showcase to evaluate and demonstrate the potentials and limits of new settlements under the utilization of proposed adaptation and mitigation guidelines. Furthermore, the study will play a crucial role in demonstrating and testing the effective application of energy construction principles. The results will be promoted to relevant stakeholders in the real estate market willing to invest in energy efficient housing and climate adapted long-term investments.

The Community Based Adaptation Scheme will focus on low-income populations that are particularly vulnerable. The aim is to involve the population early in the adaptation process in order to increase the acceptance for planned measures and the adaptive capacity of the local community. Community-based adaptation measures will range from community mobilization and awareness rising, strengthening health coping strategies related to water-borne diseases, capacity building in technical and scientific knowledge about climate change, as well as community driven adaptation strategies and actions.

The Design Catalogue on Climate-Adapted and Energy-Efficient Housing Design has been developed as part of the promotion of sustainable building practice. The development of the catalogue is based on research and modelling including the evaluation of the socio-cultural and economic context. A survey among 400 households provides information on energy consumption, mobility, environmental awareness and perception of climate change related risks. The catalogue focuses on the shophouse typology and will provide information on technical solutions in the fields of space composition, construction and material, shading and lighting, ventilation and cooling, flooding and storm water management, energy and water

Sectoral responses in the field of			
Urban flooding	**Urban climate**	**Urban energy**	**Urban transport**
Flood Protection; Water Management	Greenery & Natural System; Solar Control; Compactness	Energy Efficiency; Spatial Decentralization	Sustainable Mobility
designation of "taboo" zones for settlements designation of protected areas (nature reserves etc.) flood attenuation or provision of temporary water storage capacity separate drainage systems for surface and foul water upland and lowland reservoirs SUDS (management of quantity and quality of runoff, provision of amenity/ biodiversity benefit) increase proportion of water bodies, open water, water features one way valves permanently fitted in drains and sewage pipes to prevent backflow green roofs (run-off reduction) creative use of waste water, water efficient fixtures and fittings, rainwater harvesting and storage	increase proportion of green space infrastructure, reduction of sealed surfaces increase proportion of water bodies, open water, water features shading and orientation to reduce excessive solar gain cool pavement materials to increase of surface reflectivity orientation of buildings and streets according to wind direction and solar irradiation compact construction method: mutual shadowing of adjoining structures, shaded public spaces (arcades) cooling through increase of rainfall permeability to benefit from the cooling effect of evaporation network of 'cool' roofs	reduced land consumption through compact and qualified urban design efficient resource management with: use of recycled materials for constructing infrastructure and public spaces, the establishment of a water/ waste water management, establishment of a waste management infrastructure minimized need for cooling, minimized energy consumption by building services and minimized energy consumption by household appliances/ deployment of energy efficient technologies active and passive energy generation with neighbourhood-integrated solar heating and combined heat-cooling and Power Production Systems	reduced traffic flows with: safeguarding a diversity of uses and providing a mixed-use neighbourhood integration of appropriate social, commercial and cultural facilities within the neighbourhood integration and/ or proximity to working facilities offering differentiated housing typologies for different target groups reduced individual mobility by providing local public transport system reduce traffic flow by providing space for home work and trade in the ground floor of private houses

Fig. 35.2 Examples for spatial adaptation measures for flooding, climate, energy and transport (Source: Eckert and Schinkel 2009)

supply, and waste management and energy-saving. By providing sustainable design solutions, the catalogue will empower and encourage future home owners, architects, developers, companies in the building sector, and architecture students to respond to the upcoming discussion on sustainable living.

35.3 Summary and Outlook

The notion of climate change has arrived in Vietnam and the need for action is widely accepted among planners and decision makers. Knowledge of strategies and response options are also available to them. The decisive question seems to be how responses can be implemented. According to the National Target Program to Respond to Climate Change (MoNRE and Prime Minister 2008) – the major guiding framework for responses in and across all governmental sectors concerned – urban and environmental planning institutions are required to assess impacts of and to identify measures to respond to climate change on their respective sectors. The planning sector is also requested to mainstream climate change issues into strategies, programs, plans and planning processes and to implement structural measures and pilot projects. When identifying preconditions that have to be met by the HCMC planning system in order for it to carry out these tasks, three priorities become evident: integration, information and implementation.

The most important precondition is probably integration, since adaptation strategies have to relate to environmental conditions and land use structures, rather than sectoral or administrative boundaries. The assessment of impacts of climate change, for instance, requires cooperation of the urban administrations in charge of developing local climate change scenarios, those managing flood defence, those in charge of urban planning and development, and others. Integration and engagement of different stakeholders – e.g., universities, insurance sector, building sector, civil society – is also required. A major task of efforts towards the implementation of climate change response measures must be to enhance local capacity and facilitate decentralisation processes. Without capable local construction management offices, it seems impossible to assess and manage information on local climate change impacts, adjust national directives to local conditions and ensure the enforcement of regulations. The research project has specified opportunities for the legal integration of planning guidelines and their implementation on all levels of the urban planning system. In a further step it will also be important to test the feasibility of these planning guidelines. Therefore, pilot projects are envisaged to show the benefits of climate oriented urban design and energy efficient housing typologies.

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Chapter 36
Building Resilience to Climate Change Through Adaptive Land Use Planning in Ho Chi Minh City, Vietnam

Harry Storch, Nigel Downes, Lutz Katzschner, and Nguyen Xuan Thinh

Abstract This paper describes the adaption needs of Ho Chi Minh City and its efforts to develop and incorporate adaptation principles into its urban decision-making and planning processes. We outline an approach that is envisioned to lead to an increase in the city's resilience to climate-related physical and social vulnerabilities. This paper describes the objectives of an integrated adaptation planning framework for the city, which is intended to advance and disseminate knowledge, inform decision makers and the general public about climate change risks, and increase their capacity to implement necessary adaptation measures while strengthening the general response capacity of the urban system.

Keywords Adaptation • Climate change • Urban planning • Land use planning • Ho Chi Minh City • Vietnam

36.1 Introduction: Adaptation Research in Ho Chi Minh City

Ho Chi Minh City (HCMC) contributes a large share to Vietnam's GDP as the dominant hub of economic activity in the country. At the mega-urban scale, the issue of adaptation to climate change has received significantly less attention than the

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opportunities for mitigation. This is true despite growing evidence suggesting that the concentration of populations and economic activities within cities like HCMC make them particularly vulnerable to climate change. Due to the dense concentration of economic activities and people, HCMC can provide economies of scale and potential opportunities for innovative solutions to complex environmental problems such as climate change. With respect to vulnerability, the ultimate physical exposure to climate change will not discriminate between developing countries and highly industrialised countries. However, developing countries like Vietnam are expected to exhibit heightened vulnerability due to their lack of resources and their limited response capacity.

Climate change will likely lead to ongoing sea level rise and an increase in the occurrence of extreme weather events such as heavy rainfall and heat waves. These climate related events cause a multitude of risks, not only to natural areas, but also to the populations of densely urbanised metropolitan areas (Storch et al. 2009). It is envisioned that these events will also cause a multitude of indirect, cumulative and synergistic impacts of a severe nature, with urban flooding or disturbances to the urban energy supply and public infrastructure. The main task in the assessment of climate change related impacts at the urban level is in the estimation of the possible damages that might arise to an anthropogenically-influenced system and its assets. In general, there are two elements that define potential risk; first, the probability that an event will occur and, second, the elements themselves that are at risk. Possible events include heat waves, heavy rainfall, and flooding. Elements at risk include houses, urban infrastructure services or economic losses, but also human health and livelihoods.

Climate change represents one of the greatest challenges facing mega-urban regions of Southeast Asia, especially those that are low lying and located in intertropical coastal zones. Over the following decades, a significant amount of new urban housing developments will be required. These developments will shape the spatial pattern of urban agglomerations for decades to come. It is of the utmost importance, then, to plan how the direction of spatial development and how buildings and infrastructure in these highly vulnerable regions can be adapted to cope with the climate change related impacts they are likely to be effected by during their lifetime in an integrated manner from the outset. Due to its geographic location, this flood-prone metropolitan area will always face natural hazards. However, vulnerabilities of lives and livelihoods to climate-related environmental processes are primarily the result of inadequate and unsustainable urban planning practices. Currently, 72% of the entire urban area of HCMC lies below two meters mean sea level (Fig. 36.1).

36.2 Integrative Adaptation Planning Framework

The settlements of HCMC at the mega urban level are integrated into an urban system that is affected by a number of internal and external pressures. The impact of climate change on the city's settlements and infrastructure should therefore be

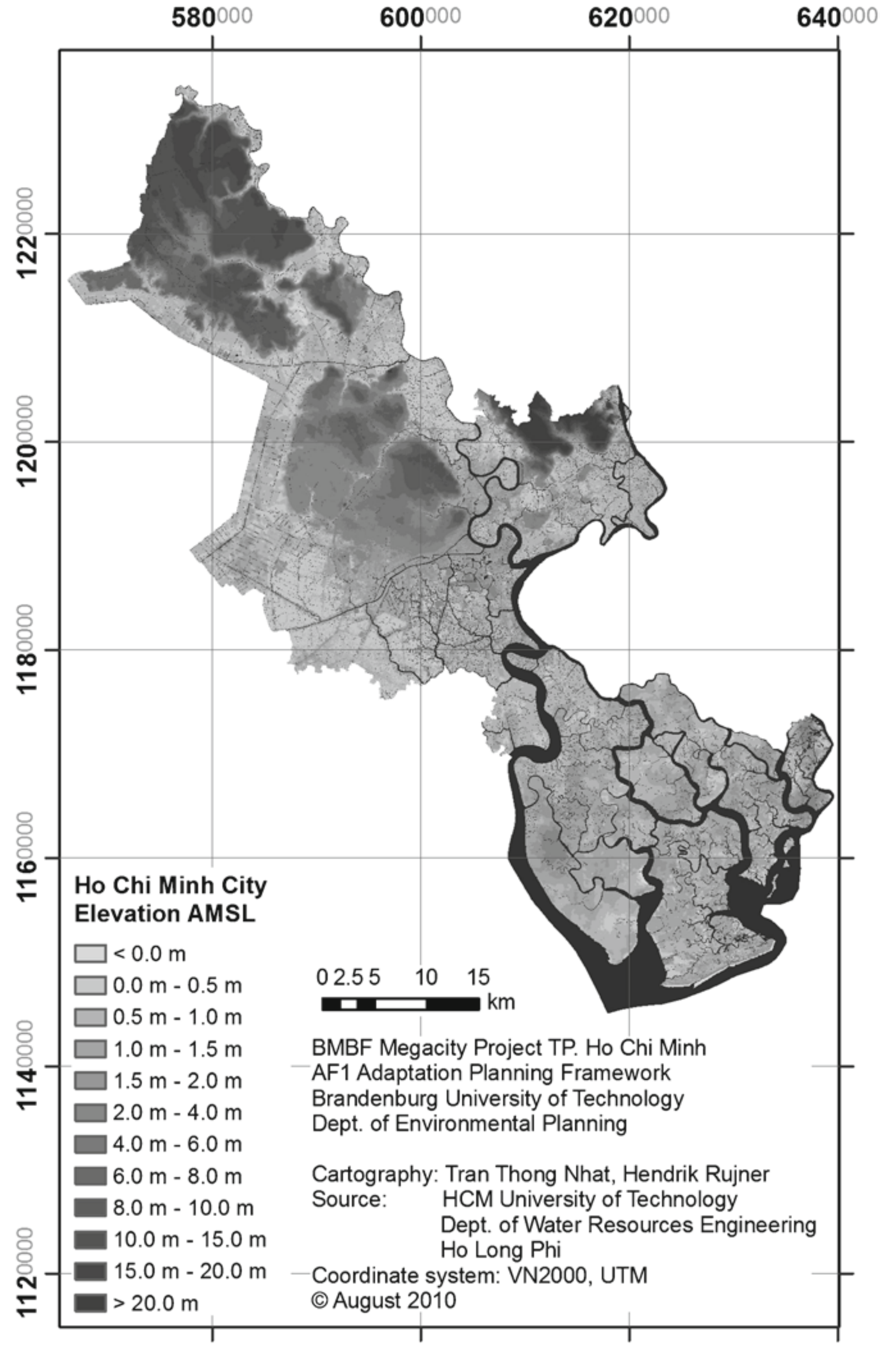

Fig. 36.1 Ho Chi Minh City districts and elevation above mean sea level

assessed in the context of this complexity. Vulnerability to climate change will vary considerably from settlement to settlement, even within settlements. Location, urban structures, dominant building types, socio-economic characteristics and institutional capacity are key factors that each influence vulnerability. HCMC consists of both planned and informal urban structures. The expansion of both these types of development has degraded valuable natural areas in the hinterland, increasing the vulnerability of these areas to climate-related environmental change (Storch et al. 2009). Furthermore, exposure and sensitivity to climate change related risks are heightened by physical processes such as construction, urban planning, infrastructure provision, as well as lifestyle choices (Clark et al. 1998).

The objective of the adaptation planning framework is to advance and disseminate knowledge, and inform decision-makers and the general public about climate change risks. This is in order to increase their capacity to implement necessary adaptation measures and to strengthen the resilience of the HCMC urban system. The concepts of vulnerability and adaptive capacity derived from the urban structure type approach aims to provide the basis for an integrated assessment of climate-related impacts and possible adaptation options. The main tasks of the framework are fourfold: (1) to compile existing vulnerability concepts from various thematic and scientific disciplines, (2) to apply indicators for spatially explicit vulnerability assessment for climate change and natural hazards, (3) to apply and improve GIS-based quantitative approaches for analyzing and modelling vulnerabilities and risks, and (4) to undertake complex spatially explicit vulnerability and risk assessments for the mega-urban region of HCMC based on advanced GIS techniques and the integration of remote sensing data for data management, data analysis and up- and downscaling within the framework of mapping vulnerability and risks.

36.2.1 Climate Change Impact Downscaled

The fundamental motivation for downscaling climate change impact assessments to the urban scale comes from the understanding that every region has unique urban development issues as well as inherent adaptation potential. More often than not, a methodological gap is found between regional climate change modelling and local urban development scenarios. This gap hinders the effectiveness of urban impact assessment methods (Fig. 36.2).

Possessing knowledge of future temperature fluctuations or precipitation and flooding trends without knowledge of the direction of urban development, limits the assessment of vulnerabilities of existing and future urban structures in relation to the future climatic conditions in the regional context. For regional climate change projections, extreme events are more important than average events. It will be difficult to predict simultaneous increases in magnitude and frequency of events. For urban development scenarios, a higher degree of flexibility is required, though a rigorous approach is essential to produce spatially explicit and comparable results.

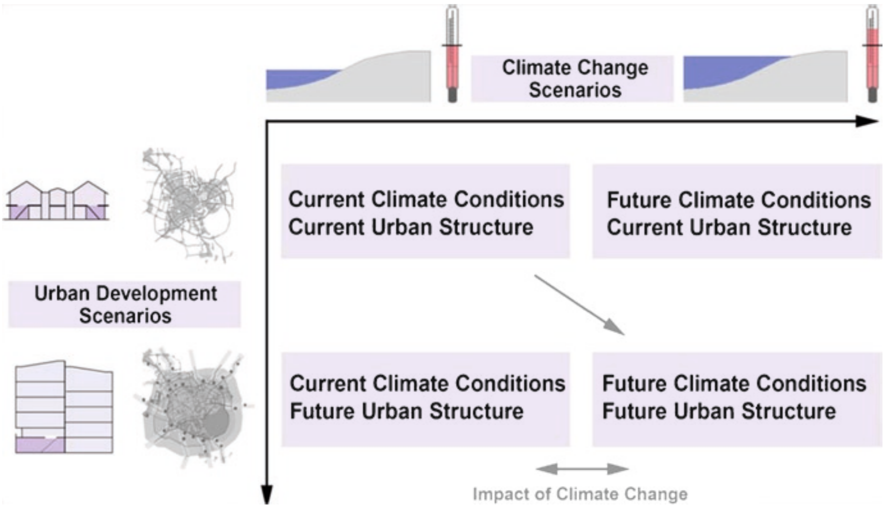

Fig. 36.2 Vulnerability assessment of climate change impacts for mega-urban regions

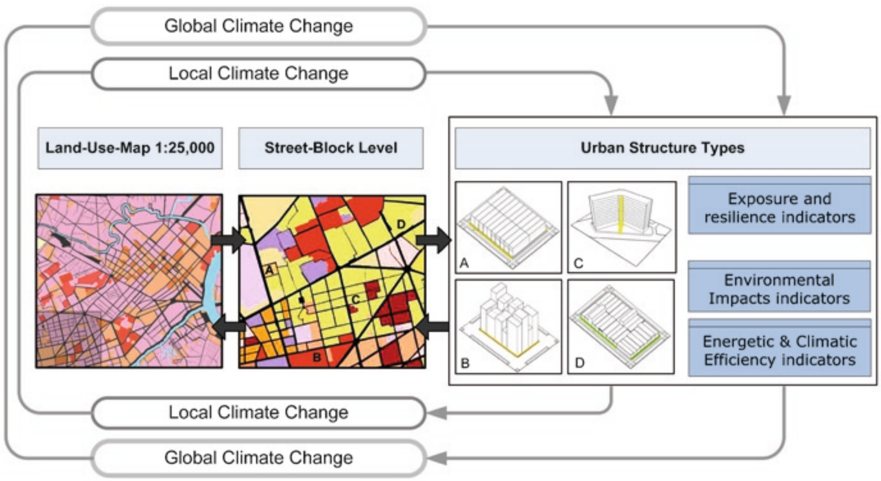

Fig. 36.3 Downscaling climate change Impacts to the urban scale

36.2.2 Indicator-Based Planning Information Systems

The urban environmental planning information system is the central instrument for integrating the requirements and measures of adaptation to climate change. This is supported by the urban structure type approach (see Fig. 36.3), which is intended to spatially link an indicator concept that represents an interpretative method to integrate the biophysical aspect of the ‘exposure’ to climate change related effects with the socio-economic aspect of assessing the ‘sensitivity’ of people and places and environmental-related information. This approach allows a multi-disciplinary identification of core indicators for spatially explicit vulnerability assessment procedures – an essential element in dealing with the inherent complexity of the urban system in Asian mega-cities. The second main function of the urban structure type approach is the definition of a commonly accepted framework to structure HCMC into comparable types of spatial areas using the official land-use map as a basis.

The structure of the indicator system represents an integrative concept, from the substantial data basis to the application–orientated modelling of initial project results. The intra- and inter-disciplinary linkages of the strategic thematic fields – urban flooding, urban climate, urban energy and urban transport – are displayed within the coordinating element adaptation planning framework. Using this specific thematic information, as well as remotely sensed data, spatial-orientated indicator base maps are generated for individual indicator sets and further refined to form analysis maps with the use of models. At the heart of the indicator system lie the official land use and urban structure type maps, which allow for a uniform scale and the ability to provide adaptation recommendations for particular urban structures. All thematic maps and analysis maps will be based upon the urban structure typology approach. Finally, planning recommendation maps and databanks containing planning relevant information will be produced. The indicator system was developed as such, so that single indicators are not intended for use in an isolated manner, but rather within an integrated framework which utilizes them as integral parts of the resulting zoning guidelines in spatially explicit planning recommendation maps.

36.2.3 Urban Structure Type Approach

The basic housing archetypes in HCMC were conceptually divided into subtypes to generate urban structure types that are reflective of different biophysical exposure, resilience or impact indicators. The physical boundaries of the housing typologies are defined by street blocks. Data representative of each housing typology will be used to formulate values for physical resilience and exposure of the building structure based on descriptive indicators. The spatial classification and subdivision of HCMC urban forms – according to urban typological principles and derived from urban environmental indicators – offers a coherent structure to support cross-scale investigations across household, neighbourhood, district and urban scales. In this respect, the developed urban structure type framework defines urban areas with homogenous characteristics, which integrate similar urban environmental conditions. Features of built-up areas, impervious surfaces, land use, housing types, building density, population density and social status of urban areas can be related for every urban structural unit. Thus, the urban structure type framework contains a whole set of biophysical and socio-economic indicators (Banzhaf et al. 2007) to characterise the state and dynamics of the urban development in space and time, as well as to foster planning strategies for adaptive urban development to climate change.

Adaptation planning to climate change in a development context requires tailored strategies for different settlement types, as spatial planning concepts are extremely dependent on the particular local urban context as the structure and arrangement of housing areas are factors influencing exposure and resilience to impacts of climate change in an urban spatial context. Recognition of this connection makes it possible to re-evaluate the housing development pattern providing planning recommendation maps as one fundamental determinant in the formation of urban vulnerability to climate change. The exposure and resilience pattern for each housing development helps to determine the ultimate vulnerability of the urban region to climate change. Different settlement types will have different implications for vulnerability. Urban resilience and exposure are strongly influenced by the choices that are made regarding which housing types to build (Storch and Schmidt 2006, 2008). The urban structure type approach offers discipline-specific approaches as a commonly accepted spatial working basis, which can ensure that the resulting heterogeneous investigations can be integrated in a transdisciplinary manner by using an adequate spatially explicit classification.

36.3 Adaptation of Land-Use Planning Policies to Climate Change

As a certain degree of climate change is now seen as unavoidable, the decision makers of HCMC require sound information from scientific impact assessments to understand and evaluate adaptation options and potentials. Vulnerability to climate change depends upon HCMC's physical, social and institutional characteristics, for example, on the resilience and location of building stock and critical urban infrastructure, as well as on the types of businesses operating and how public services are provided. One critical issue is to understand how urban developments interface with climate change. HCMC's urban structure, form and density are defined over time, so reducing vulnerability will require concerted effort over a much longer time horizon. As a result, today's urban development decisions will have a critical influence on the future vulnerability of HCMC to climatic change. Understanding the urban-scale risks of climate change is critical for administrative decision makers to anticipate changes and to manage climate related impacts and risks more efficiently.

The right portfolio of urban policies is particularly important to ensure that long-lived infrastructure – commercial and residential buildings, roads and ports, water and transport networks – are designed to withstand the expected increase in climate hazards while simultaneously improving the energy and emission performance of the built environment. Integrated urban planning is central to land use decisions and zoning that may exacerbate or limit the exposure and vulnerability of urban dwellers and infrastructure to the growing threat of climate change. Within this article, the thematic research fields of urban flooding and urban climate and the corresponding adaptation potentials are outlined. The chosen themes promote vertical and horizontal feedbacks and connections between the integrative thematic fields. An adapted urban planning system is envisioned to deal more effectively with the future challenges of climate change, as spatial planning must not only take into account land use activities, but also the social, economic and environmental well-being of communities.

36.3.1 Urban Flooding in HCMC

In recent decades, the occurrence of flooding events has become one of the most pressing issues for HCMC. The objectives of the thematic focus area of urban flooding are to determine conflict areas and vulnerability for different flooding situations within HCMC, to compile flood hazard maps for the city, as well as to develop strategies and measures for efficient flood risk management. A hazard map will outline the spatial distribution of flood damages of previous events, whereas the risk map will display possible damages for a given probability of occurrence. The consequences of the current and future flooding events of HCMC are manifold, including loss of life and personal injury, direct damage to property, infrastructure and utilities, contamination and disease from flood and sewage waters, loss of income and delayed economic development, break up of communities and social connectivity, blight of land and development, as well as increased insurance costs.

Even within the thematic field of urban transport, interconnections exist. The investigation of the future challenges for urban transport management must consider high demographic growth, strong changing consumer habits and transportation trends, which have to been seen in combination with other climate change impacts such as urban flooding caused by heavy rainfall events or through climate induced sea level rise. These present pressing challenges for future land use and transportation system planning, which must be taken into consideration when developing adaptation strategies for the future.

Figure 36.4 emphasizes the problems of urban flooding for the mega urban region of HCMC. The central business district of HCMC (Quan 1) dealt with 63 separate flood incidents in 2008 alone, while the adjacent district of Quan Binh Thanh recorded 246 separate flood events over the same period.

36.3.2 The Urban Climate of HCMC

The process of urbanisation brings several reasonably well documented micro- and meso-climatic changes (Landsberg 1970, 1981). Environmental planners will have to deal with these issues. Problems with fresh air circulation now plague many cities in tropical areas. Within the city, wind direction and air circulation are closely controlled by the form of the buildings, the spatial pattern of streets and open spaces and by the topography upon which the city is built. Urban climate maps can thus highlight that uniform building height and uniform distances between build-

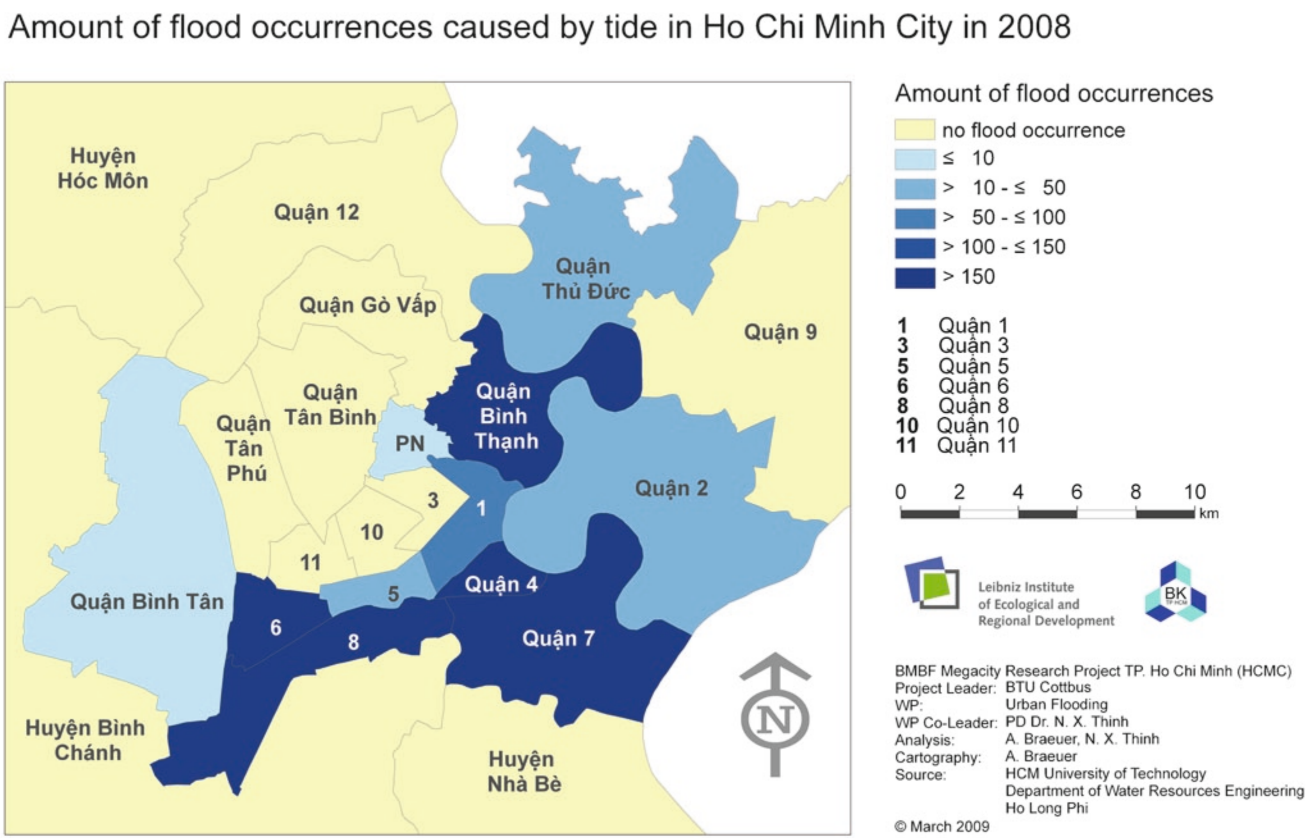

Fig. 36.4 Amount of flood occurrences caused by tide in HCMC districts for the year 2008

ings create the least flow disturbances, while the analysis of local fresh air corridors and thermal circulation patterns provide solutions on how to improve construction and developments (Katzschner 2009).

Within the field of urban climate studies, two types of maps are commonly applied – urban climate maps and urban climate recommendation maps (Scherer et al. 1999; Ren et al. 2007). The urban climate map is also often termed a 'climatope' map, as it displays different climatopes, areas of distinct local climates (Kuttler 1993). The idea behind this approach is that different urban structures such as downtown districts or suburban areas, but also parks or large water surfaces, interact distinctively with the urban atmosphere (VDI 1997). Further, the urban climate map is defined in a classification system following regional climatic characteristics based on different regional urban structures. An urban climate map can be considered an appropriate tool for transferring and displaying urban climatic parameters such as fresh air corridors, parameters for thermal comfort and the urban heat island effect, into the planning process. Such a map for HCMC would allow information over the existing urban fresh air corridors to be displayed in a readable manner and provide assistance to avoid or minimise thermal stress.

The planning recommendation map is based upon the urban climate map and aims to provide planners and architects with recommendations from an urban climate perspective. For example, the map represents areas that require improvement and enhancement and areas which should be conserved and protected from the viewpoint of urban climate, as shown in Fig. 36.5. It also represents the results of an evaluation of the urban climate. While the legend of the urban climate map represents the planning guidelines following different strategies – e.g., protection

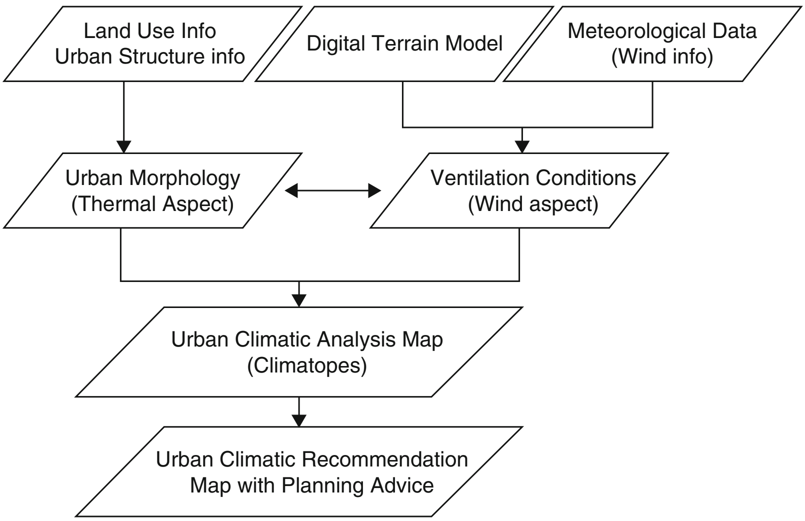

Fig. 36.5 Principle work flow and input in a GIS based urban climate analysis

of sensitive areas, improvement of problematic situations, risk assessment and reduction – it also makes recommendations for appropriate forms of land use.

For inhabitants of HCMC, thermal issues also have major importance with respect to both pollution and environmental health issues. High heat stress can only be partially mitigated by the utilisation of air conditioning units; however, at the scale of the entire city, the energy requirements are astronomical. Here a strong connection exists with the thematic focus area of urban energy. Naturally, then, increased ventilation and air exchange to reduce thermal stress is required. To provide a picture of local heat stress situation, the Physiological Equivalent Temperature (PET) indicator is commonly used. This indicator has been shown to be applicable in high dense Asian cities (Katzschner 2009).

36.3.3 Administrative Integration and Planning Recommendation Maps

In HCMC, urban policy making and the implementation of adaptation strategies involves multiple levels of governance. This requires vertical coordination among local and regional governments, and the horizontal coordination among the range of agencies engaged in climate policy. To address climate change in mega-urban regions, the most important modes of urban governance for local policy actions are land use zoning, environmental and water resource management, transportation and building. Land-use planning has wide-ranging and long-term effects on all sectoral policies for adaptation to climate change. Spatial planning effects the form and structure of the built environment, influencing the vulnerability of HCMC's urban environment. Urban master planning and land-use zoning policies determine the array of land uses that are permitted in a particular zone. These decisions shape the built environment and determine the exposures and risks to climate related natural hazards.

Within the interdisciplinary approach, the overall objectives are to determine adequate adaptation measures for land-use planning at the urban level by minimising the significance of core conflicts on human health, flooding and climate. Sector planning objectives and designation zones are analysed on the basis of their importance for climate change and compiled in a clear way. As the implementation of sectoral policies has much stronger spatial consequences on urban land use and development than comprehensive land use planning policies, their position in adapting to climate change must be strengthened and their integration level assessed. Thus, essential contributions of sector planning to urban planning have been identified and compiled in a systematic way (Table 36.1).

Land use planning is a key criterion of effective strategies to deal with climate change challenges. Adaptation is unrealisable without improvements in the usability of scientific results for decision-making and their integration into the planning process. To identify and estimate the local risks arising from climate change, the research will support the HCMC administration to establish a well-founded database

Table 36.1 Designation criteria and measures for adaptation to climate change, compiled for integration into the land-use plan

Environmental media	Urban planning objective	Receptor: environmental state in urban planning	Potential environmental impacts	Potential measures and adaptation response
Human health	Protection of population against floods	Settlements in retention areas of rivers or close to coast	Increasing water levels causing flooding	Resettlement
			Increased urban flooding from overflow of storm drains	Designation of retention and infiltration areas
				Buffer zones
				Hard protection measures i.e. dyke systems
	Protection of population against urban heat islands	Cities of high building density	Air pollution	Designation of sanitation areas (desealing etc.)
			Land consumption	Designation of climate protection areas (cold air protection areas and fresh air corridors)
			Fragmentation of fresh air corridors	Increasing evaporation
Fauna flora biodiversity	Protection of natural rural areas and inner-urban green spaces	Environmentally important areas	Air pollution	Creation of restriction zones and inner-urban greens paces
			Land consumption	
			Decrease of groundwater level	
Water	Remediation of rivers and retention areas	River catchment areas	Decrease of groundwater level	Designation of retention and infiltration areas
			Dehydration of lakes and rivers	
–	Remediation of groundwater regime and wetlands	Wetlands, grasslands, agricultural areas	Decrease of groundwater level	Designation of retention and infiltration areas
–	Reduction of surface runoff	Urban settlement	Flooding	Designations for increasing evaporation, infiltration and rain water utilisation

with reliable information. Based on this data, maps incorporating planning advice in reference to measures (restrictions, bans, conditions and development objectives) will be provided for HCMC's planning administration. In this respect, the same area may contain significant unsealed surfaces, or exhibit infiltration, retention and/or evaporation potential. In addition, the same or adjacent area may also render itself suitable for preferential roof greening, the development of retention water bodies or the protection of riparian buffers. Utilising the adaptation planning framework approach outlined above, the overall aim is to combine the planning recommendation maps in order to guide zoning for the protection of the values and features of a multi-functional landscape pattern in the peri-urban fringe.

The official HCMC land use plan itself displays only the planned designation of land uses, not current land use. Inherent qualities of are not illustrated; i.e., the environmental significance of an area, the exposure or resilience of areas or structures, or urban structural density. For measures and planning recommendation maps, an initial differentiation between the restoration of the existing asset and the planning guidelines for new designated areas has to be undertaken. Using the example from the urban climate and flooding viewpoint, the focus here is on recommendations and measures for the protection of green and open spaces. Additionally, the fundamental guidelines for new development sites will be suggested; i.e., regulations regarding building height, building density, and soil sealing.

36.4 Summary and Outlook

The government of HCMC should act now to develop a mega-urban strategy for adaptation to the inevitable impacts of climate change. The status of climate change science in Vietnam is strong. However, within a mega-urban agglomeration such as HCMC, there is still a need to expand the understanding of urban climate change research and to refocus on the spatial and temporal distribution of the most severe impacts and potential responses. Observable climate change is already affecting a broad range of human and natural systems and will pose more significant risks in the future. In this critical field of research, an emphasis should be placed on action-oriented and use-inspired research. Outcomes should be useful to decision makers at the local and urban level while acting to limit the impacts of climate change.

A variety of climate related impacts such as rising sea level and the intensity and frequency of extreme tropical weather events including heavy precipitation and heat waves are already affecting the urban area of HCMC. The reduction of vulnerabilities in this area is a highly desirable strategy to manage and minimize risks. Administrative decision-makers need to anticipate a range of possible climate impacts. The current uncertainty regarding the exact timing and magnitude of impacts should not be seen as a reason to delay response. Adapting to climate change will be an ongoing, iterative process, and will involve decision makers at every spatial scale from all sectors of urban government and society within HCMC. To best support and provide decision makers with information for the evaluation of adaptation options that will ultimately improve the overall resilience in a mega-urban region, the main task is to identify vulnerabilities to climate change impacts on smaller spatial scales.

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Chapter 37
Climate Change Risk Management for a Suburban Local Government: The Case of Kogarah, Australia

Elisa Idris and Hartmut Fünfgeld

Abstract This paper examines the risk management process undertaken by Kogarah City Council to address climate change impacts using the tools and resources developed by ICLEI – Local Governments for Sustainability through its Adaptive and Resilient Communities Program. The paper focuses on the experiences, challenges and learnings of the council when working through the different stages of the program. It highlights some of the strategies and initiatives Kogarah City Council has implemented in order to achieve its main climate change adaptation goals and objectives. This paper is therefore intended as a 'case study' for other local governments planning to carry out a risk management process within their organisation. It is concluded that the key immediate outcome of the program for Kogarah City Council was internal capacity building that was achieved by enabling staff to collaboratively engage with each other in a structured and facilitated manner.

Keywords Adaptive management • Climate change adaptation • Climate change impacts • Local governments • Risk management

37.1 Background

It is now evident that our climate is changing and our world is warming. Despite all efforts to reduce greenhouse gas emissions, overwhelming scientific evidence indicates that some degree of climate change is inevitable and will become a serious

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global threat that requires urgent preparation (Stern Report 2006; Garnaut Review 2008; IPCC 2007; DCC 2010).

Almost all sectors of society, including the economy, are likely to be impacted by climate change, either directly or through society's response. Adapting to these impacts will mean taking action to reduce the adverse consequences of climate change, and taking advantage of any opportunities climate change may present. Adaptation to climate change will involve adjusting policies and operations to help prepare our ecosystems, infrastructure and communities to cope with climate change impacts. The decisions made today will have lasting consequences. It is therefore important not only to assess climate change impacts currently being observed, but to also begin planning for future impacts.

37.2 Impact of Climate Change in New South Wales, Australia

In Australia, changes in key climate parameters have changed significantly over the past decades. Since 1960, the mean temperature in Australia has increased by about 0.7°C, with some areas experiencing substantially higher rates of warming, from 1.5°C to 2°C (CSIRO/Bureau of Meteorology 2010). These conditions have also led to an increase in days with record hot temperatures and prolonged heat waves. The decade from 2000 to 2009 was Australia's warmest on record. During the 1960–1990 period, rainfall patterns have changed, with most of the state of New South Wales (NSW) experiencing a decrease in rainfall of 5–50 mm per decade (ibid.). Decreasing rainfall has been most severe in the coastal areas of New South Wales (ibid.). The increase in mean temperature, combined with a decrease in rainfall, has led to an increase in bushfire risk for large parts of south-east Australia. During the period of 1993–2009, mean sea level was observed to have risen between 1.5 and 3 mm per year in southern and eastern Australia (ibid.). With around 85% of Australia's population living within 50 km of the coast (Australian Government 2009), sea level rise is considered one of the key climate change impacts for the nation. Sea levels are projected to rise up to 40 cm above the 1990 mean level by 2050, and 90 cm by 2100 (DECCW 2008).

37.3 Climate Impacts on Local Governments in Australia

Local governments (known as *councils* in Australia) will be at the forefront of identifying and addressing climate change risks and opportunities, as they are likely to implement the climate change legislation and policies developed by higher levels of government. Being the tier of government closest to the community, it is also expected that the information and regulatory needs of different parts of the community (residents, property owners, small and medium sized businesses) will have to be met by local government. This includes appropriate guidance on local development and general obligations towards residents in a changing climate (ICLEI 2010).

A study on adaptive capacity towards climate change by the Sydney Coastal Council Group (Smith et al. 2008) states that councils have the responsibility for both identifying potential natural hazards within their boundaries, including those associated with climatic events, and for granting development approvals. Councils have a duty-of-care to ensure that development decisions take climate change into account and that new developments are not exposed to current or known future hazards. Although councils have always had the task of determining the local character of the municipality through land use and development planning, climate change has made this process more complicated. Councils now not only have to consider historical climate variability but also future climatic changes, even if the rates, magnitude and spatial distributions of these changes are still uncertain (Smith et al. 2008).

Local government operations and business processes that may be affected by climate change include infrastructure and property services, recreational facilities, health services, planning and development, natural resource management as well as water, stormwater and sewerage services.

A survey of NSW local governments found that an overwhelming 70% of councils do not feel confident about their level of preparedness for climate change (Urbis 2010). Out of the councils surveyed, only a third had undertaken a risk assessment to predict the impacts of climate change (Urbis 2010) (Fig. 37.1).

37.4 Kogarah City Council – A Suburban Local Government in Australia

Kogarah City Council (KCC) is located approximately 15 km south of Sydney, on the east coast of Australia. The city lies along the northern shoreline of the Georges River with over 16 km of river foreshore. The council area is approxi-

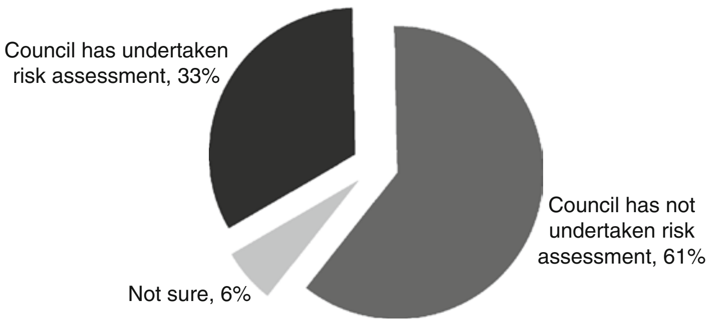

Fig. 37.1 Percentage of New South Wales councils that have undertaken any form of risk assessment relating to the impacts of climate change (Urbis 2010)

mately 1,460 ha, with 184 ha of open spaces consisting of parks, reserves, bushland and foreshore areas (Kogarah City Council 2009). These bushland areas contain more than 140 different species of plants and support a number of native animals, including birds, reptiles, as well as the ring-tail and brush-tail possum (Kogarah City Council 2009). The city's population is approximately 53,000 and its landscape is predominantly urban residential (Kogarah City Council 2009). The city also hosts a number of recreational facilities and advanced medical services of regional importance.

The region is particularly vulnerable to the risks of climate change due to its low topography, significant development close to the foreshore and aging assets (stormwater systems, buildings, seawalls). In this respect, KCC is representative of urban Australia – 50% of the country's residences are located within 7 km of the coast (ABS 2005). This trend is set to continue with population growth rates in coastal Australia nearly 60% higher than the national average (ABS 2005).

37.5 Risk Management Approach to Adaptation

As there are uncertainties associated with both the magnitude of future climate change and its impacts on the natural and built environments, a risk management approach is ideally suited to managing climate change adaptation from a local government perspective. This has been advocated by the Australian government, which has developed a framework for the assessment of the risks associated with climate change based on the Australian and New Zealand Standard AS/NZS 4360 Risk Management[1] (AGO 2006). According to this framework, this involves the following steps:

- Establishment of the context
- Risk Identification – what are the risks?
- Risk Analysis – what is the likelihood and what are the consequences?
- Risk Evaluation – what are the biggest risks?
- Risk Treatment – how do we manage the risks?

37.6 Adaptive and Resilient Communities (ARC) Program

The risk management approach described above has been adopted by ICLEI – Local Governments for Sustainability Oceania for its capacity-building and decision support program on climate change adaptation called Adaptive and Resilient Communities (ARC). This program has recently been integrated into a larger programmatic framework on climate change response for local government, called Cities for Climate Protection – Integrated Action (CCP-IA) and is now known as the CCP-Adapt stream within CCP-IA.

[1]This standard has since updated to AS/NZS ISO 31000: 2009.

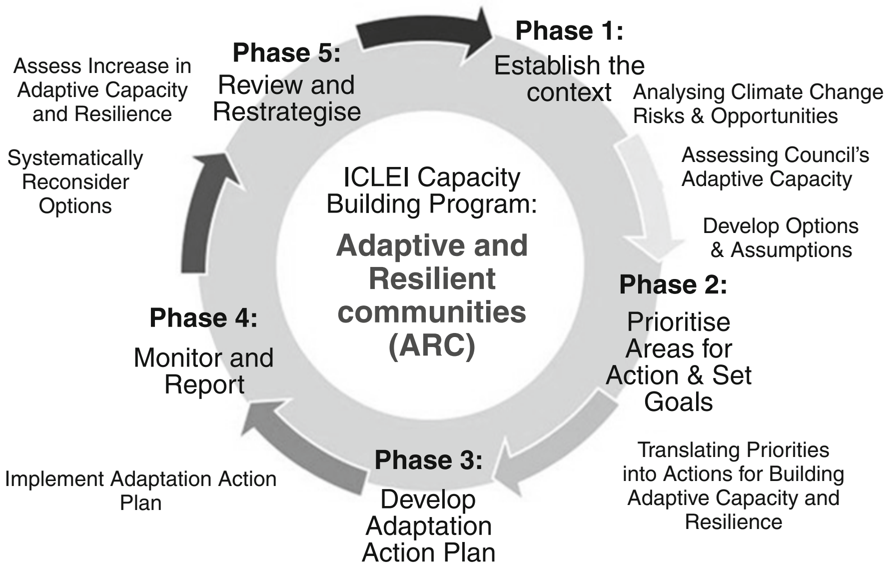

Fig. 37.2 The five phases of the ARC Program (ICLEI 2010)

The ARC Program incorporates a climate risk management process in an adaptive management framework. This framework enables councils to make decisions on climate change adaptation despite scientific and political uncertainties. This is achieved by enabling councils to take action based on the best information available at a particular point in time, and later revisiting their decisions to determine how effective and appropriate they have been. The ARC Program is carried out through a five-phase process (see Fig. 37.2):

- Phase 1: Establishing the context and identifying climate change risks.
- Phase 2: Prioritising areas for action and setting goals through risk analysis and evaluation.
- Phase 3: Developing climate change actions through risk treatment.
- Phase 4: Monitoring actions and reporting on progress.
- Phase 5: Reviewing and re-strategising.

Further information and details on the methodology, tools and resources of the ARC Program can be found on ICLEI Oceania's website (ICLEI 2008, 2010).

37.7 Kogarah City Council's Risk Assessment Process Through the ARC Program

Between July 2009 and October 2010, KCC completed the first three phases of the ARC Program. The methodology and tools adopted were provided by ICLEI through their online wiki platform, as well as assistance provided through meetings and teleconferences. In addition, KCC has worked closely with two other Sydney local governments to share learnings from each phase through ICLEI facilitated workshops. The process was of great benefit, enabling all participants to learn from each other's experiences – both positive and negative – whilst also enabling ICLEI to deliver the program cost-effectively and improve the program methodology based on participant feedback. The regular meetings with other local governments provided an incentive to contribute and advance through the different program phases. KCC found that the following pre-requisites are essential for successful implementation of the ARC Program:

- High level commitment from CEOs, mayors or councellors. To gain this high level commitment, a business paper was presented to the councillors stressing the need for KCC to assume its responsibilities and legal liabilities from a climate change perspective. KCC adheres to the precautionary principle within its management and operations, and is thus committed to managing risks as soon as they come to light. Addressing issues such as emergency management, asset management and service efficiency, all make good business sense – regardless of what the drivers are. These arguments were well received by the council.
- Dedicated staff, preferably with some background on environmental management or risk management to champion the process within the organisation. KCC dedicated two employees to work on the program, one for approximately 60% of working hours and the other for approximately 20% . It is also important to recognise the need for training and improving the skills of those involved in the program.
- Making discretionary funds available for obtaining resources and tools as required throughout the program. KCC funded the project through its Environmental Levy Program and committed to funding for the next 4 years to ensure its longevity.
- Obtaining independent expertise in the field to guide and assist the facilitation of the risk assessment process. KCC received significant help from ICLEI Oceania through teleconferencing, workshop facilitation, ongoing advice, documentation, resources and material review. In addition, an online wiki platform was created by ICLEI for knowledge management and resource sharing between participating local governments and ICLEI.

37.7.1 KCC Climate Change Adaptation Working Group (CCAWG)

A first key step in the ARC Program was the establishment of a Climate Change Adaptation Working Group (CCAWG) across the council's departments and hierarchy. The Working Group has become the main avenue of internal stakeholder consultation for the ARC Program. To ensure that climate change adaptation was integrated into the council's core business operations, it was important to achieve a cross-departmental collaboration within the Working Group. KCC's CCAWG members included representatives from the council's departments of Sustainability, Strategic Planning, Engineering, Assets, Finance, Legal, Recreation and Urban Landscapes, Community Services, Catchment Management, and Geographical Information Systems (GIS).

The members of the Working Group have to some extent become 'champions' in raising awareness on climate change impacts and the associated risks and opportunities within council and beyond. For this purpose, the Working Group was also comprised of members from different hierarchical levels within the organisation to ensure the vertical integration of climate change considerations. Commitment to the Working Group was driven by higher level management. The responsibilities of the CCAWG were clarified at the outset using a terms of reference template provided by ICLEI.

From KCC's experience, beneficial personal traits of those involved in the Working Group include an open mind, willingness to share but not dominate, dedication and consistency in attendance and contribution. Creating and maintaining these values within the Working Group has shown to produce the best results in the risk management process. The recruitment of motivated staff members into the working group is therefore key in achieving success.

One of the challenges faced was that some climate risk management activities or decisions require a group consensus. The qualitative risk assessment process, for instance, required reaching consensus on the likelihood and consequence ratings of risk. It was found that it can be difficult to reach consensus in a large group if there are a minority of members who are vocally pushing for a certain outcome. The larger the group, the longer it can take to reach a consensus. If the group is too large, a consensus may never be reached, which may jeopardise support for the overall process. To manage this issue, the Working Group was split into smaller 'Urban System Groups' (e.g., planning, infrastructure, community and governance) when required. The default resolution would be to apply a worst case scenario perspective when a consensus on, say, the level of risk could not be reached.

37.7.2 Communications Brief and Stakeholder Analysis

A communication strategy and brief is one of the requirements of the ARC Program and serves to guide the direction of the project. It ensures that all key decisions are communicated to the relevant stakeholders. To date, communication on climate change adaptation has been focussed internally to KCC's staff.

A key finding of the program was that communicating climate change should not be underestimated. It is important to identify target audiences and tailor key climate change messages to these, seeing that it can be assumed only few message recipients would have a sound understanding of climate change issues. In addition, local governments typically find it difficult to carry out a 10 year plan, let alone comprehend and communicate the concept of planning for the next 100 years, which may be required in the case of climate change adaptation.

The most successful message delivered internally at KCC was that the council needs to needs to manage climate change adaptation for a variety of reasons, including: duty of care, ensuring good business management by reassessing and re-evaluating council's activities, sound asset management, emergency management, and maintaining high quality community services. The focus, therefore, moved away from an environmental perspective to a sustainable business agenda. The next important step for KCC in fleshing out its communication brief is to determine how best to communicate with the wider community.

37.7.3 Establishing the Context for Climate Change Adaptation

By establishing the context of the risk assessment, key climate change risks to the council and within the municipality were more appropriately identified. This phase involved selecting a potential future scenario of climate change which the council (i.e., elected local representatives) then adopted to enable climate change risks to be evaluated. The ARC Program emphasised the adaptive management principles of documenting the reasoning behind the selection. Documentating the decision-making processes can be an important factor when transferring knowledge and showing that the council has acted in good faith, using the best available information, when making decisions (ICLEI 2008).

For its risk assessment process, KCC adopted the A1Fl emissions scenario (IPCC 2007), which represents a global future based on intensive fossil fuel use with continuously growing greenhouse gas emissions. The selection of this scenario over others proved to be a difficult exercise as there were few precedents to consult and significant unknowns relating to the consequences of any of the choices. A particular concern was potential liability issues for KCC if a more optimistic, lower emissions scenario was adopted to guide planning and decision-making. There was little guidance from recognised bodies or higher levels of government; therefore, the council acted based on its own research to arrive at the best decision at the time. In selecting the A1FI scenarios, KCC has applied the precautionary principle in planning for the worst case, acknowledging that current global greenhouse gas emissions are tracking above the A1FI projections.

The establishment of a scoping statement within the ARC Program has been valuable in defining the boundaries of the climate risk assessment process and in helping to determine KCC's circle of influence and control. By agreeing on the scope of the risk assessment, the council was able to focus on the key risks and impacts identified within this scope rather than trying to include all aspects of climate change in the risk assessment and adaptive management process.

During the scoping process, the CCAWG recognised the importance of being clear and explicit on what the initial assessment was to encompass and what it was to exclude. In order to adequately define the climate risk management process, the scope description needed to cover the operational boundaries, the geographical area, the organisational boundaries, and the time horizon of the assessment. To define operational boundaries, KCC resolved to focus on the risks and opportunities that climate change presents to its *own* operations and services, and will endeavour to mitigate these risks and reduce the organisation's vulnerability. Priority was given to adaptation measures that also benefit the community, and will cover a period of 20 years (to 2030).

37.7.4 Risk Analysis

Once the cope of the process was defined, KCC undertook a risk analysis by assessing the likelihood and consequences of the identified climate change impacts using the ARC Program tools provided by ICLEI. This helped to identify what impacts presented the greatest risk. Under each impact, a number of specific issues were then identified through conceptual modelling techniques. The top four impacts that were considered of greatest risk to KCC are presented in Table 37.1.

37.7.5 Conceptual Modelling

A mind mapping technique was then used to identify the factors associated with each of the impacts. The mind mapping process identified factors that could contribute towards successful adaptation to each identified climate change impact. Conceptual models focused on an adaptation 'target condition', which the council aims to achieve in regard to a specific impact, were developed for each key impact during an interactive ARC Program workshop and subsequent CCAWG meetings. Consultation with various departments on each of the conceptual models was also

Table 37.1 Risk priority levels

Impact	Likelihood	Consequence	Risk rating
Impact 1: Increased impact on council's foreshore areas (sea level rise, water table and erosion)	Almost certain	Moderate	High
Impact 2: Increased quantity, frequency and severity of rainfall events cause flooding and overland flows	Almost certain	Moderate	High
Impact 3: Increased frequency of severe storms and weather events	Almost certain	Moderate	High
Impact 4: Increased average temperatures	Almost certain	Minor	Medium
Overall impact: Increased pressures on council's resources (financial, time, staff, skills) and its capacity to adapt	Almost certain	Major	Extreme

carried out. This conceptual model development process and consultation took approximately 2 months, with staff contact time amounting to approximately 30% of this period.

Conceptual modelling is a discursive brainstorming technique that aims at facilitating structured, creative discussion about a clearly specified issue – in this case, an identified climate change impact. It uses a classified sequence of 'direct factors', 'indirect factors', 'components', 'conditions' and 'leverage points' to help structure a discursive exploration of what adaptation measures may be needed to reach a pre-defined adaptation target condition. Conceptual modelling proved to be a challenging concept for some of the staff members involved in this process. Often the conceptual models became quite complex, taking up considerable space with several layers of indirect factors, factors that influence multiple other factors and components of the model, and a mix of direct and indirect leverage points. Presenting the resulting conceptual models in an easy to read manner was a challenge that required visual software tools, which needed to be readily accessible and user friendly to the CCAWG members. At times, it was difficult to grasp the end result of the process and what was meant to be achieved from the exercise. Despite being a time consuming and complex process, conceptual modelling was found to be the most appropriate method in encouraging critical and lateral thinking within the group; it brought out questions and possible solutions that might not otherwise have been considered.

37.7.6 Risk Evaluation and Prioritisation

The ARC Program promotes the use of 'issue briefs' to provide a risk rating for each issue. The issue briefs are useful tools to develop or outline assumptions and are intended to be revisited and revised throughout the adaptive management process. KCC's issue briefs included a risk ranking for two time frames, which was a modification to the original ARC process. The two time frames (2030 and 2100) were adopted by KCC because it was felt that the level of risk (likelihood and consequence) for each issue was different for an intermediate and long term future. Adopting two time frames helped to prioritise adaptive management actions for the short term and for the long term, and made it easier for the Working Group to comprehend the risks associated with each issue. Actions which KCC could take to mitigate the risks were identified, along with estimates of KCC's cost for mitigation, and the possible benefits to the community from mitigation. These factors are considered when prioritising risk reduction or mitigation actions in the next stages of the program.

Each issue brief contains a list of the relevant assumptions, risk assessment, and possible mitigation measures of the issue, as well as all subsidiary issues. Establishing assumptions was one of the most important steps for KCC within the risk assessment process, as this will allow for adaptation measures to be revisited at a later stage and revised or updated based on changing assumptions. To enable

Fig. 37.3 Prioritisation chart: prioritising issues as areas for action (ICLEI 2010)

adaptive management practices, it is highly recommended that all assumptions are carefully documented and revisited throughout the program.

Through this process, each issue was allocated a quadrant within the risk prioritisation chart (see Fig. 37.3) developed by ICLEI (2010). This three-dimensional matrix plots each issue or impact according to:

- Risk rating – low, medium, high or extreme
- X-axis: the estimated benefits to the community by responding to this issue
- Y-axis: the estimated Council costs of responding to the issue

An example of the Kogarah City Council's prioritisation chart for sea level rise is shown in Fig. 37.4. In this example, it was identified that KCC should immediately address the issues located within the bottom left quadrant due to the high community benefits achievable from responding to these issues and the minimal costs to the council. On the other hand, KCC should start planning for the issues that are located in the top left quadrant, as responding to these issues provides significant community benefit but at a higher cost to Council.

This tool was extremely beneficial for the council as it provided a snapshot of the issues that could be realistically managed and those that provided the greatest benefits. During the discussions, issues beyond the council's control were also effectively put into perspective.

Target condition: **Resilient/adaptive to Sea Level Rise**

2030 Estimated community benefits

Estimated resources requirements	Very high	High	Medium		Low	Negligible
Very high		8. Degradation or decreased public open space/recreational area due to SLR	4. Costly foreshore infrastructure adaptation due to infrastructure damage and deterioration	10. Loss of biodiversity (flora and fauna) due to increased water table / SLR	9. Declined or loss of waterfront property values due to SLR	
High					12. Increased salinity issues along Council's foreshore due to increase in water table	
Medium	1.Failure to adopt or adopting inappropriate SLR benchmarks (lack of information) for planning purposes	2.Failure to adopt or adopting inappropriate SLR benchmarks (lack of information) in Flood Management Plans	5. Insufficient communication with residents/ businesses on SLR	6. Inappropriate tool selection for communication with residents/ businesses on SLR	7. Potential liability due to approving developments which did not considered/take account of sea level rise	
Low					13. Increased erosion along Council's foreshore	
Negligible		11. Segmented/ disjointed approach on SLR by Council (without regional or state collaboration)	3. Failure to utilise best practice technology when designing foreshore structures (Capital Works Plan)			

	Consequences				
Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	High	Extreme
Possible	Low	Medium	Medium	High	High
Unlikely	Low	Low	Medium	Medium	Medium
Rare	Low	Low	Low	Low	Medium

Fig. 37.4 Kogarah City Council's prioritisation chart for sea level rise: 2030 (ICLEI 2010)

37.7.7 Risk Treatment Through an Action Plan

Through intensive risk evaluation from previous phases of the program, KCC gained an appreciation of the intended ideal outcome for each climate change issue. This was then used to develop goals and objectives for each climate change issue. Goals were assessed against the organisation's strategic directions and tested to meet the SMART criteria (Specific, Measurable, Achievable, Realistic and Time-specific). KCC then ensured that the goals, objectives and action were established in accordance to its new 10 year Community Visioning Plan, 'Bright Future, Better Lifestyle – Kogarah 2020' (Kogarah City Council 2010). Such alignment of goals is intended to reinforce climate change considerations with the highest level of the council's strategic planning documents. A climate change action plan was then produced through the collation of the goals, objectives and actions for each issue.

37.8 Kogarah City Council's Main Achievements

KCC's most important accomplishment from this program has been the internal capacity building within the organisation. By undertaking the program internally (rather than outsourcing the work), KCC gained complete ownership of the identified actions and effectively integrated climate change considerations within the council's business operations and governance. This work has also encouraged employees to start considering and assessing the risks of climate change impacts within their work. Now as part of their working agenda, it is on track to become fully integrated within the council's business and supply chains by 2012.

Involvement with the ARC Program has resulted in invaluable experience and learning. This includes internal and external collaborative work, the integration of new science and climate data in the council's work, identifying previously 'untapped' adaptive management skills of employees, and previously unidentified levels of knowledge/skills on climate change. These capabilities within the organisation have effectively been brought to light through the implementation of the program.

37.9 Conclusion

Under conditions of uncertainty, a risk management method was found to be the most appropriate process to manage climate change adaptation in KCC. The Adaptive and Resilient Communities Program provides a practical framework that addresses the needs of local governments in their efforts to manage the risks of climate change impacts.[2] In the context of using the planning and decision-making tools made available through the program, considerable capacity-building needs were identified in the course of the process, which should be taken into account when carrying out a risk management process. This paper highlighted Kogarah City Council's learning process and recommendations in order to enable other local governments to improve their own climate risk management. Aside from the tangible outcomes of this process, Kogarah City Council's main achievement was increasing its internal capacity to address climate change impacts.

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Chapter 38
Climate Change as a Survival Strategy: Soft Infrastructure for Urban Resilience and Adaptive Capacity in Australia's Coastal Zones

Nan Chen and Peter Graham

Abstract This paper outlines the conflicts and synergies between risk and resilience approaches to climate change adaptation planning in vulnerable coastal areas of Australia. It examines whether current planning processes shaping vulnerable coastal settlements in Australia are sufficiently informed to build adaptive capacity for their communities under climate change impacts. Considerable research to date has focused on the application of risk management in identifying vulnerabilities and predicted worst-case scenarios. This approach often proposes 'hard' infrastructure changes for climate change adaptation. However, little work has been done looking at the processes for implementing and supporting such adaptation strategies while addressing the inherent uncertainty of future climate change impacts. This so-called 'soft' infrastructure is critical to building a community's ability to innovate and prosper while adapting to unforeseen challenges posed by a changing climate. It is argued that introducing concepts of resilience to municipal planning processes for vulnerable coastal settlements, particularly in development control plans (DCP's) may provide a more comprehensive approach to climate change adaptation.

Keywords Climate change adaptation • Resilience theory • Risk management • Urban planning • Vulnerable coastal settlements

38.1 Introduction

Climate change is threatening the sustainability of coastal communities around the world. Settlements in Australia's coastal zones are no exception (Harty 2008; Australian Government House of Representatives Standing Committee on Climate

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Change 2009). Due to climate change, some of the most populous of these areas are experiencing greater intensities of severe weather, and greater fluctuations in drought and flood cycles (Australian Greenhouse Office 2006; Stokes and Howden 2008). Municipalities in these areas are therefore active in identifying areas of vulnerability and developing policies to minimise risks. While these measures may help protect people from worst-case scenarios, they may not be enough to effectively adapt to climate change? Drawing on resilience theory, it could be argued that climate change adaptation requires that communities not only have the ability to withstand and absorb impacts, but also the ability to self-organise and learn as change occurs. Adaptation, therefore, requires both resilient built-environments and supple municipal institutions.

The issue of climate change offers an imperative to reform each of these aspects of coastal settlements. To this end, opportunities for reforming development control planning as a nexus between institutional processes and built-form should be considered. This paper explores this potential by reviewing the conflicts and synergies between risk and resilience approaches to climate change adaptation planning in vulnerable coastal areas in Australia. It argues that uncertainty about future impacts of climate change require a combination of risk and resilience-based adaptation strategies.

38.2 Climate Change Adaptation as a Survival Strategy

Increased awareness among policy makers that climate change will continue despite the best mitigation efforts has recently raised the profile of adaptation as a critical issue. Plans are increasingly being developed to deal with the threat of rising seas, drought, spreading disease, and other projected impacts of a warming world. Recent Australian research has shown that climate change is unpredictable and likely to be 'more rapid and severe, and more costly and dangerous than previously thought'. Projections of climate change impacts in Australia are now at or above the worst-case scenarios (CSIRO/Australian Government Bureau of Meteorology 2009).

Studies of the influence of human activity on the climate reveal a complicated relationship between energy use, development and climate change; each are interdependent and reliant on basic ecosystem services.[1] Municipal planning authorities have therefore begun to search for planning strategies that can better deal with the complexity and uncertainty of environmental, social and economic

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[1] Ecosystem services include: *provisioning*, such as the production of food and water; *regulating*, such as the control of climate and disease; *supporting*, such as nutrient cycles and crop pollination; and *cultural*, such as spiritual and recreational benefits (UNMA 2004).

systems; i.e., social–ecological systems. As these systems are constantly interacting and changing, built-environment planners and decision-makers must develop integrated processes to continually revise climate change adaptation and mitigation policies in order to achieve socio-economic development goals (Davoudi et al. 2009).

However, recent studies of municipal planning processes in Australia's vulnerable coastal settlements have shown a lack of engagement with climate change adaptation, and where adaptation *has* been considered, it is often not well integrated into mitigation strategies. This lack of integration of mitigation and adaptation is now increasingly recognised as undermining the effectiveness of municipal strategies for addressing climate change (Swart and Raes 2007; Davoudi et al. 2009).

Municipal climate adaptation strategies often promote technical responses, which result in increasing investment and construction of physical (hard) infrastructure to protect against worst-case impact scenarios. However, as impacts of natural disasters such as Hurricane Katrina in New Orleans exemplify, hard-infrastructure alone is not sufficient for adaptation and can even fail to perform their primary role of protection if the institutional (soft) infrastructure is inadequate (U.S. House of Representatives 2006).

The potential benefits of creating and effectively implementing a more diverse set of strategies for developing the adaptive capacity of the entire municipal socio-ecological system – rather than merely preparing for particular impacts – needs investigation. Municipal planning in Australia therefore requires climate change adaptation policies that not only integrate mitigation as an essential component, but which are also adaptive themselves to a changing policy environment. While threats of climate change are being addressed, less attention has been given to generating survival strategies.

38.3 Vulnerable Australian Coastal Settlements

Approximately 80–90% of Australians are now living within 50 km of the coast. More than 700,000 homes and billions of dollars in assets and infrastructure are at risk from rising sea levels and storm surges (Australian Government DCC 2009). At the same time, coastal settlements are becoming increasingly important in terms of population growth and investment. Australia, therefore, must resolve competing pressures on its coastal zone between, on the one hand, economic drivers and the sustainability of coastal settlements, and on the other, the safety of its residents in relation to the impacts of climate change.

The vulnerability of urban areas to climate change is a function of social, economic and political development processes (Dawson et al. 2009). The predicted consequences of climate change in Australia are severe. Climate change is likely to have the following impacts in Australia:

- Significant loss of biodiversity is projected to occur in some ecologically rich sites, including the Great Barrier Reef and Queensland Wet Tropics.
- Water security problems are projected to intensify in southern and eastern Australia.
- Production from agriculture and forestry is projected to decline over much of southern and eastern Australia.
- Ongoing coastal development and population growth in some areas of Australia are projected to exacerbate risks from sea level rise and increases in the severity and frequency of storms and coastal flooding (IPCC 2007).

For any city, the risk from climate change is greatly influenced by the quality of housing and infrastructure in that city, the extent to which urban planning and land-use management have successfully ensured risk reduction within urban construction and expansion, and the level of preparedness among the city's population (e.g., access to key emergency services).

Australia is already experiencing the economic, social and ecological implications of climate change. The country has seen its average temperature increase by 0.9°C since 1950, while climate change impacts have become more severe, frequent and rapid than predicted (IPCC 2007; SMEC Australia 2009; CSIRO 2009). Buildings, settlements and infrastructure have been identified as having the most potential to benefit from early climate change adaptation planning, particularly on the coasts (COAG 2006). However, due to a historic lack of policy in this field, many municipalities must start from scratch. There is therefore increasing pressure on municipal planners to urgently address these issues.

38.4 Australian Urban Policy Responses to Climate Change Adaptation

Australia's settlements, particularly those in the coastal zones, are vulnerable to climate change. This is not only due to extremes in temperature and precipitation, but also due to a lack of institutional (or soft) infrastructure (CSIRO 2006). Prior to 1970, there was little building regulation and almost no planning laws that gave consideration to preparing for natural disasters (Morgen 2006). Although Australian municipalities are now realising the importance of designing adaptation strategies for vulnerable settlements, many barriers to the implementation of soft infrastructure still exist. Findings from policy studies at both the municipal and national levels have clearly identified the problems confronting municipal climate change adaptation agendas:

- While urban development planning has a key role to play in building the adaptive capacity of urban areas, there is little understanding of how development planning currently addresses, or tries to facilitate, climate change adaptation at the municipal level.
- Climate change adaptation strategies tend to be generic and sparsely implemented.

- The use of risk management approaches to inform climate change adaptation strategies alone are not adequate to deal with the concurrent, interdependent and dynamic nature of urban change and climate change.
- While there is an abundance of hard infrastructure strategies available to provide adaptive capacity in coastal settlements, soft infrastructure for effective implementation is significantly lacking.
- There is lack of stakeholder involvement and of fundamental knowledge about climate change issues. In addition, linear cause-and-effect approaches for predicting and resolving climate change impacts are insufficient given the complexity of the interactions between climate systems and human settlements.

Under the above conditions, identifying co-benefits and possible adverse side-effects of adaptation strategies is difficult (Pittock 2003). New forms of adaptation planning are therefore beginning to be investigated. Toward this end, the recent National Climate Change Action Framework recommended that:

- The Australian Building Codes Board consider climate change as part of their periodic review of building standards;
- The data used to determine vulnerability of settlements to climate related hazards (floods, bushfires, cyclones and coastal inundation) be reviewed; and,
- New or revised risk management guidelines be developed to take into account any projected changes as a result of climate change

In response, the Australian Building Codes Board has established a climate change research and policy framework to help ensure building codes consider potential future effects of climate change. There is also work underway to develop an interactive web-based tool to enable planners, engineers and policymakers to incorporate projections of high sea-level events into their planning codes. Local government is at the forefront of managing the impacts of climate change and the Australian Government is providing funding to help local governments prepare their communities for those impacts (COAG 2007).

However, at the municipal level, settlement planning for vulnerable coastal settlements in Australia neither adequately incorporate climate change adaptation into the planning process, nor effectively ensure that stakeholders are aware of the trade-offs inherent in any coastal settlement planning (Smith et al. 2008). There is clearly a need for change in thinking about municipal planning. Given the broad spectrum of issues within this field, key leverage opportunities need to be identified, such as development control planning.

38.4.1 Importance of Development Control Plans as Soft Infrastructure

The future shape of urban areas is often described within legal planning instruments such as development control plans (DCPs). DCPs provide a fundamental piece of soft infrastructure for climate change adaptation and are executed as legal instruments to set compliance requirements for developing, designing and constructing built environments. Local governments use such tools to anticipate and engineer changes in order to maintain a certain quality of life within communities. The process of development control planning and approvals has been identified as a key potential climate change adaptation action for local government (SMEC Australia 2009).

The Local Development Performance Monitoring Report 2006–2007 (the first analysis of its kind) found that Australian municipalities dealt with 112,000 development proposals, comprising 86,000 development applications, 14,000 modifications and 11,000 complying development certificates during that year (Environmental Planning and Assessment Amendment Bill 2008; Building Professionals Amendment Bill 2008; Strata Management Legislation Amendment Bill 2008). As the nexus between what is planned and what is actually constructed, development proposals are an influential element of soft infrastructure. However, the kinds of development controls that could be developed to facilitate adaptation and their effectiveness will be influenced by the dominant epistemologies and information available. The following section argues that development control planning could be more effective if dominant risk-management approaches to identifying adaptation priorities are augmented with resilience planning techniques.

38.5 Risk and Resilience-Based Approaches to Urban Planning

Current coastal planning for climate change adaptation in Australia is predominantly based on risk approaches. These rely on projections and probabilities of past events to inform decision-making (DPCD Victoria 2008). In particular, coastal planners are under pressure to find ways to prepare for the potential impacts of future climate change while dealing with immediate pressures (Byrne et al. 2009). At the same time, climate change poses challenges for ecosystem and resource management; decisions on how to respond to future risks are complicated by the temporal and physical scales, and the uncertainty associated with the distribution of impacts. It is not surprising that local authorities with limited financial support and personnel can feel disempowered by the global scale and sources of risk, which often manifests as an excuse for inaction (Pelling 2003; Smith et al. 2008). Risk-based approaches may provide good information for planning for predicted impacts, but are less effective in planning for adaptive capacity – the ability to maintain services when unexpected changes occur.

There is increasing concern that traditional planning decisions, based on extrapolation of the probabilities of environmental disasters reoccuring and human vulnerabilities, are no longer sufficient for developing policies on climate change adaptation. It could be argued that, while risk approaches help plan for worst-case scenarios, there is still a need to seek new approaches that incorporate risk into changing circumstances. Development control planning in the face of climate change uncertainty requires not only predictive understanding, but also dynamic understanding of the possibility of learning, adapting and prospering with change. A built environment shaped by these principles may be qualitatively different than one shaped predominantly by risk preparedness and avoidance. The institutional soft infrastructure, then, would need to become equivalently supple. Given the potential limitations of risk-based planning, theories of resilience may offer a new way forward.

38.5.1 Resilience-Based Approaches

The concept of resilience emerged in the 1960s and early 1970s through studies of responses of species to ecosystem dynamics which led to the development of ecological stability theory (Odum 1971). In his landmark article, 'Resilience and Stability of Ecological Systems' (1973), the ecologist Holling described for the first time the existence of multiple equilibriums of natural systems, and how they respond to external disturbance. He introduced resilience as the capacity of a system to persist despite experiencing both internal and external change: 'resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist' (Holling 1973:17).

Holling, for the first time, articulated the multiple equilibrium character of ecosystems. His insight on the dynamics of ecosystems has been observed by others; namely, May (1977) who investigated the thresholds and breaking points that trigger multiple stable states; Timmerman (1981) who made the initial links between vulnerability, resilience and social systems; and Walker et al. (1981) and (Ludwig et al. 1993) whose research provided more empirical findings. These insights and findings have challenged the dominant view of single equilibrium and global stability that used to inform policy-making.

Since the late 1980s, the concept of resilience has increasingly been used in the analysis of human–environment interaction, mainly to describe and understand how humans affect the resilience of ecosystems. Gradually, social and ecological theory were brought together with empirical findings to analyse the structure and function of ecosystems, and how institutions and people associated with ecosystems (social–ecological systems) are organized (Berkes et al. 2003). The seminal 'Barrier and Bridges to the Renewal of Ecosystems and Institutions' (Holling 1995) emphasized the importance of managing learning *by* change rather than trying to *control* change; in other words, uncertainty and change is 'part of the play' (Folke 2006). From this perspective, we need to learn to prepare for and live with such dynamics (Carpenter et al. 2001). This is key to resilience theory, which is in contrast to conventional single equilibrium views that understand environmental problems more from a cause-and-effect perspective.

Resilience theory, in essence, accepts dynamics, surprise and uncertainty as naturally embedded in social–ecological systems. Folke et al. (2002) identified key attributes of resilience in social–ecological systems:

- The ability to absorb disturbance without changes in patterns and shifts to other sets of keystone processes.
- Essential sources of resilience lie in the diversity of functional groups within the system, accumulated experiences and memories that assist in the reorganization and renewal processes.
- Resilience resides in both fast and gradual changing elements of the socio-ecological system.

Attempts to address resilience in social–ecological systems should consider linking these attributes to practice and decision-making process. Recent work has investigated such issues in relation to coastal development (Adger 1999, 2000; Adger et al. 2005), vulnerability of cities (Pelling 2003; Pickett et al. 2004; Newman et al. 2009) and adaptive governance (Armitage et al. 2007; Bullpitt 2008). Nevertheless, investigating the link between climate change adaptation and social–ecological resilience – e.g., the capacity of a system to adapt to climate change and continue to develop and prosper – requires further research and policy development (Folke and Gunderson 2006). More specifically, the potential for resilience theories to inform development control planning for climate change adaptation remains under-investigated.

38.6 Conclusions

Application of resilience theories to municipal planning requires considering the built environment as nestled within a social–ecological system. From this perspective, the resilience and adaptive capacity of the built environment depends on:

- the amount of shock that the built environment can absorb while providing basic services;
- the degree to which the built environment is capable of self-organizing; and
- the degree to which the built environment can learn through change.

Municipal planning policy for climate change adaptation is currently informed by risk-management approaches that identify vulnerabilities in relation to the first point, emphasising the development of hard-infrastructure. However, due to the inherent uncertainties associated with future climate change impacts in vulnerable coastal settlements, risk-based approaches are not sufficient to determine the needs of soft infrastructure, such as municipal capacities for self-organisation and learning to adapt to climate change. While some work has begun to investigate the potential for resilience theories to inform urban policy, more specific focus on development control planning as the nexus between policy and built-form may yield more comprehensive approaches for planning to adapt and prosper under climate change.

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Chapter 39
Curitiba, Brazil: A Model for Resilience in Latin America?

Peter Spathelf

Abstract During the 1960s and 1970s, Curitiba, the eighth largest city of Brazil and the capital of the Brazilian federal state of Paraná, experienced a demographic expansion of up to 5.7% annually. The implementation of progressive environmental policy in Curitiba dates back to this time. During this period, city authorities began to create parks and preserve the remnants of natural forests. A master plan for urban development was implemented beginning in the 1970s. By 1998, 1,100 permanent preservation sites had been established within Curitiba's special green area sector. Arborisation (i.e., tree-planting) of the city's streets was also intensified. Today, Curitiba has about 50 m^2 of green area per capita. According to current regulations in Curitiba, the felling of isolated trees requires a permit from the Environmental Secretary. The city also takes advantages from a state law that provides tax benefits for the sound management of conservation areas. As this paper discusses, a significant part of the city's population is involved in environmental programmes to support poverty alleviation and reduce livelihood vulnerability. Although problems still persist within the city, Curitiba is well known for its policy in favour of well-ordered urban development, sophisticated public transportation systems and environmental conservation – attributes that give Curitiba its reputation as a modern resilient city.

Keywords Arborisation • Poverty alleviation • Resilient city • Urban greening • Urban planning

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39.1 Introduction

Trees outside forest, or TOF, are all trees located on land not defined as forest or other wooded land; these include trees growing in parks and gardens, around buildings, and along streets, roads, railways, rivers and canals (Kleinn 2000). The importance of TOF in providing goods and services for society is increasingly recognised by institutions involved in land use planning and management. In countries with low forest cover, TOF constitute the main source of tree products. In recent years, great effort has been made to collect data on TOF at the national and international level and to initiate a broad dialogue on the subject. This has resulted in greater attention given to urban forestry issues (Spathelf 2002). In industrialised countries, the goals of urban forestry are to create environmental benefits, such as equilibrated temperature regimes, fresh air sources, and support for recreation. In developing or newly industrialised countries, however, urban forestry covers more urgent needs, such as soil protection, human nutrition and job creation (Kuchelmeister 2000).

Although every Brazilian city contains some parks and squares, co-ordinated development of the green area sector is often lacking. The problem has less to do with the maintenance of trees and parks in downtown areas than it does with the uncoordinated and chaotic urbanisation process occurring at the periphery of big cities. This horizontal expansion is characterised by clandestine development of land, which is often unsuitable for buildings. The absence of sound housing policy and tenural security in most of these areas has lead to significant geographical segregation of residential areas, which has in turn resulted in social stratification. In most cases, the basic infrastructure of housing, health or waste disposal cannot be guaranteed. There is thus just as little a concern for environmental policy. Nevertheless, in some Brazilian cities, major urban forestry activities have been documented (e.g., in Rio de Janeiro, Recife, Porto Alegre and Curitiba).

39.2 The City

Curitiba is the eighth largest city of Brazil with 2.42 million inhabitants (greater Curitiba) and one of the regional metropoles of Brazil. The city is located on the first highland plateau of Paraná at an altitude of 905 m above sea level. Towards the east, the nearly 2,000 m high coastal mountain range delimits the highlands from the coastal zone (distance, 80 km). Further urban growth and expansion is still possible towards the north, west and south. The climate is subtropical humid, with occasional frosts occurring at night during the winter. The natural (forest) vegetation in the highlands surrounding Curitiba consists of tropical moist mixed forest (‘floresta ombrófila mista’) with a predominance of *Araucaria angustifolia* in the upper storey and a variety of broad-leaved trees in the lower storey. Today, however, only small fragments of Araucaria forests remain. The natural vegetation of the coastal range in the east of the Curitiba metropolitan area is a dense tropical moist (cloud) forest, the so-called 'Mata Atlântica.' Only 3% of the original 61 million hectares of this forest type in Brazil remains today (FAO 1993). A significant fragment of 'Mata Atlântica' near Curitiba is preserved as a UNESCO biosphere reserve.

The implementation of a progressive environmental policy in Curitiba dates back to the 1970s. The demand for recreation and leisure areas increased as populations grew rapidly. In parallel with urban expansion, access roads to residential areas received linear green zones ('jardins ambientais'). Cycleways with 'green' components were built along railway routes. Polluted areas with disordered development were treated and transformed into 'green' areas. The city's authorities also began to create parks and preserve the remaining gallery forests in order to improve natural draining. Parks and groves were named according to different immigrant ethnicities (e.g., German grove, Pope grove) to support cultural identification. The arborisation of the city's streets was intensified with the planting of 70,000 trees (the annual mean number of trees planted since then is 3,000). Moreover, environmental education programmes were launched to help shape an environmentally friendly attitude among citizens.

Recently, the metropolitan area has experienced another period of accelerated growth due to intensified industrialisation; e.g., through the establishment of international companies such as Renault and Volkswagen. Former suburbs – not only capitals themselves – often profit from industrial and population growth. This is the case with São José dos Pinhais, 40 km south of Curitiba, where the establishment of a Volkswagen plant and a new airport has led to exorbitant growth and land consumption.

39.3 Urban Planning and the Green Sector

Despite these problems, Curitiba is well known beyond its national border for its policies in favour of well-ordered urban development, sophisticated public transportation systems and environmental conservation. Each of these attributes has contributed to Curitiba's reputation as a modern model city in Latin America. During the last 30 years, Curitiba has focused on its urban planning. A master plan for orderly urban development was implemented during Jamie Lermer's administration in 1971. The development of the master plan was accompanied by the efforts of the Urban Research and Planning Institute of Curitiba (IPPUC) as well as permanent discussions throughout society (e.g., 'Tomorrow's Curitiba' seminars). Today the city is moving forward to extend its solutions to the whole metropolitan area. The special 'Municipal Secretary for Metropolitan Affairs' links Curitiba to the governments of 24 surrounding municipalities. Recently, the city's administration launched 24 inter-divisional 'core idea projects' for the metropolitan area with timetables for execution.

In 1973, the former Forestry Department (today, Brazilian Institute for Environment and Renewable Natural Resources) transferred the legislation

Table 39.1 Important environmental legislation in Curitiba relating to urban planning and TOF

Name of law, decree	Subject
Law 4557/73	Protection and conservation of trees
Law 5234/75	Zoning of land use
Decree 400/76	Preservation of riparian zones
Law 6819/86	Formation and preservation of green areas, tree compensation planting
Law 7833/91	Environmental policy
Decree 471/88	Establishment of municipal parks
Law 8353/93 and Decree 782/95	Parameters for occupation of real estates, criteria for tree cutting
Municipal Forest Code 1998 (not yet passed)	Collection of all environmental relevant legislation

Table 39.2 Type, number and size of conservation and leisure units in the city of Curitiba (Source: Secretaria do Meio Ambiente 2000)

Types of green area	Number	Area (m²)
Parks [a]	14	18,407,873
Forests (groves, 'bosques')	12	612,295
Squares	351	2,017,789
Gardens ('jardinetes')	289	303,839
Places ('largos')	52	58,571
Environmental gardens ('jardins ambientais')	6	51,100
Sport centres	2	64,100
Environmental cores	11	6,676
Animation axes	14	417,118
Total	751	21,939,361

[a] Parque Iguaçu, the largest urban park in Brazil with a total area of 8,264,316 m²

responsibility for Curitiba's green areas to the city authority. Green areas were defined as native forests in order to protect water, soil, fauna and scenic assets, and to exclude plantations of fast-growing exotic species like *Eucalyptus* and *Pinus* (for law 6819, see Table 39.1). The former city's park directory was also connected directly to the mayor's office. In 1991, new environmental laws established general measures of environmental protection, conservation and melioration within the capital. After several organisational changes, the Environmental Secretary of Curitiba is now in charge of the supervision and monitoring of parks, isolated trees and conservation areas, as well as the arborisation of streets. In 1974, 93 areas of tree vegetation, which belonged to former permanent preservation areas, were mapped and registered. In 1998, 1,100 forests of permanent preservation had already existed within Curitiba's special green area sector (forests of permanent preservation are native forest remnants on real estate within the municipality).

As a special category of the green area sector, preservation areas ('Unidades de conservação e lazer') like parks, groves or squares were delimited (for a summary of these areas see Table 39.2). The specially protected areas as well as the forests of permanent preservation underlie the local municipal norms. Today Curitiba has about 52 m² of green area per capita, which is controlled and monitored by the municipality. Recent surveys even indicate an increasing trend in green area, but with strong variations throughout the different town districts (e.g., the city centre accounts for only 5 m² per capita). The UN Health Organisation's recommendation is 12 m² of green area per capita (Secretaria do Meio Ambiente 2000). The development of legislation relating to TOF systems in Curitiba is documented in Table 39.1.

The main goal of Curitiba's parks and green area policy is to create compensation areas in the 'urban ecosystem.' Parks and groves are connected to leisure areas in order to support environmental education of the population, especially for children and pupils. Curtiba's philosophy promotes the role of green areas in the urban environment to further guarantee sound urban development. Another goal is the preservation of typical vegetation (forest) formations of the region. One of these parks, which turned out to be one of the symbols of Curitiba, is the new Ukrainian Memorial Park. Created with a botanical museum, this park shows one of the few remaining native forest fragments of *Araucaria angustifolia* within the urban area. Another example is the German grove with a secondary forest consisting mainly of deciduous trees. In the south of Curitiba, a new park was recently dedicated to Brazil's 500th anniversary. More areas will be delimited soon, especially in the periphery.

According to current regulations in Curitiba, the felling of isolated trees requires a permit from the Environmental Secretary (see so-called 'árvores imunes de corte,' Table 39.3). If permission is obtained, two trees of recommended species (four in the case of *Araucaria angustifolia*) have to be planted or donated to the city by the landowner. The trees and forests in the city's special sector of green areas no longer lose their designation as being forest. This means that in the case of forest degradation or destruction, the forest must be fully restored. Soil occupation of the city's real estate is regulated in detail by the size and vegetation cover of the real estate. Furthermore, the landowners in the special sector of green areas are encouraged to preserve forest fragments by being offered a reduction or suspension of property tax proportional to the forest cover registered on their land. The city also benefits

Table 39.3 List of tree species that are prohibited from cutting ('árvores imunes de corte') in Curitiba

Scientific name	Popular name
Chorisia speciosa	Silk floss tree
Populus nigra	Poplar
Castanea vesca	Chestnut
Eucalyptus spp.	Eucalypt
Araucaria angustifolia	Brazil pine/Parana pine
Araucaria bedwillyi	Bunya pine
Tipuana tipu	Rosewood, pride-of-Bolivia
Schizolobium parahybum	Yellow jacaranda
Olea europea	Olive tree
Carya illinoiensis	Pecan tree

from a state law (the so-called 'ICMS ecológico'), which allows the city to keep 5% of value added tax from the state on the condition that it manages conservation areas or forests that contain springs. Thus, Curitiba gets R$300,000 weekly, which can be spent on ecological measures. A special fund (Municipal Environmental Fund) was created to allocate the money from surcharges, donations and other sources in order to establish environmental priorities. Currently, Curitiba is discussing a further extension of environmental regulations within a municipal forest code.

39.4 Arborisation Studies

There are few detailed studies that assess the condition of green areas and street trees in Curitiba (Milano 1984, 1988; Roderjan and Barddal 1998). Based on a systematic inventory, street trees were sampled and identified including crown and root characteristics, as well as diseases and other damages. In total, 4382 trees were investigated. Of the 93 species found in the study, 92% were made up of only 18 species. The two most abundant species (*Lagerstroemia indica* and *Ligustrum lucidum*) account for 39% of the population. This poses a great risk because *Lagerstroemia* is highly susceptible to fungi. One third of the trees were damaged. Three percent of the trees caused damages to streets due to superficial root systems. Many of the trees were also observed to have already reached electrical lines, which in most cases led to improper and unprofessional tree pruning. The spacing between the trees in general was found to be sufficient. In general, the city's arborisation practices were considered adequate.

39.5 Urban Forestry in the Context of Environmental Initiatives

Today, a significant part of Curitiba's population is involved in environmental programmes. There are several activities in the field of environmental education; for example, 'Olho d'Água,' where municipal students carry out survey programmes about river quality, or 'Câmbio Verde,' where recyclable trash is exchanged for food or teaching material. The Municipal Health Secretary also supports the production of medicinal plants, which are freely distributed to local health stations. In a project called 'Cesta Metropolitana,' fruits are sold 30% below market price, especially for poor people from peri-urban areas. Although there are no explicit projects in the field of urban agriculture in Curitiba, small producers of the metropolitan area do have the right to sell their products at special markets without middlemen.

In terms of local participation, Curitiba's most successful environmental project is the communal planting project, 'Plantios Comunitários'. Supported by the Environmental Education Department, native (fruit) trees are planted with the help of local people. Once suitable areas are determined, the department contacts local representatives to involve them in the planning process. Areas chosen for planting are always public, and often threatened by erosion or inundation, like steep slopes or riparian zones. Local people are also provided with specific knowledge about the tree or shrub species. These activities are not restricted to the city centre, but tend to focus on the periphery of the urban agglomeration.

39.6 Conclusion

In comparison with other Latin American cities, Curitiba is undoubtedly a positive model for Latin American urbanisation. Experience over the past decades in Curitiba has shown that successful urban forestry programmes require integration into sound environmental and social policy. Urban greening, then, can be viewed as a means for poverty alleviation and as a contribution to a more co-ordinated urbanisation process. Curitiba's focus on environmental policy shows a promising way out of the development blockades of Latin Americas cities. Curitiba's current engagement in various innovative networks, such as PLUS/Sustainable Cities or the Global Partnership on Cities and Biodiversity further catalyses its development towards urban sustainability.

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Part V
Approaches to Climate Change Adaptation in Cities

Chapter 40
Introduction: Approaches to Climate Change Adaptation in Cities

Hartmut Fünfgeld

The academic and policy discourse on how cities can best address the impacts of climate change is still relatively new and often mainly concerned with how city administrators, politicians and civil society leaders can best access and interpret the latest climate change science to assist in their local decision-making processes.

The ability to understand climate change scenarios and the local relevance of global climate modeling is without a doubt key to climate-sensitive local planning and decision-making. However, for urban planners and decision-makers within local government, the journey does not stop there. As climate change observations and projections become more readily available, the more difficult (and likely more relevant) challenge is how this information can be interpreted systematically within the local context in order to provide meaningful guidance on local climate change impacts. Addressing questions of climate risk – their identification, analysis and evaluation – warrants examining recently developed and tested frameworks and approaches to urban climate change adaptation. This represents the scope of the papers presented in the following chapters.

Over the past few years, an increasing number of conceptual frameworks, guidebooks and toolkits for adaptation have emerged, some of which were presented during a series of sessions at the Resilient Cities 2010 Congress. Frameworks and toolkits are necessary catalysts for climate change adaptation as they provide 'how-to' guidance on adaptation planning processes in order to assist local government planners and decision-makers in systematically addressing climate change impacts. However, the planning processes suggested in such prescriptive frameworks are rarely straightforward enough to implement at the city level and often fall short of addressing the uncertainty inherent in climate change data. Toolkits can help open the door to climate change adaptation and provide useful starting points, but the institutional, socio-economic and cultural characteristics that differ between countries requires a significant degree of flexibility as well as the 'bottom up' input of

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knowledge, particularly when it comes to identifying effective and locally appropriate adaptation measures. Adaptation frameworks, then, must remain true to their meaning by being readily adaptable themselves. They must provide approaches that appropriately frame the process of climate change adaptation, while being flexible enough to accommodate local systemic differences.

What seems to be critical from a learning perspective is examining city case studies where particular adaptation planning approaches have been successfully implemented, filtering out key lessons where local characteristics were accommodated (or not) during the process. The following chapters feature a mix of contributions, some of which focus on conceptual frameworks for adaptation and their implementation in cities, while others illustrate practical adaptation measures. The latter include concrete examples of how climate change adaptation at planning and operational levels has been put into practice, ranging from urban green space development to urban design.

Based on such practical experiences, it should be possible within the coming years to develop international inventories of adaptation frameworks that have successfully been implemented at city level, including their caveats, as well as databases of tested adaptation measures that respond to particular adaptation needs (e.g. sea-level rise in protected coastal wetlands).

As the tremendous interest in Resilient Cities 2010 and similar international conferences show, cross-organizational learning from the implementation of practical adaptation measures is a process that is still in its infancy, though considered highly important. Building the knowledge base and enabling knowledge transfer on local adaptation practice is critical for catalyzing action in this emerging field of work.

Along with a growing understanding of which adaptation measures work in particular contexts – and which do not – we will likely see a further increase and specialization of tools and toolkits for climate change adaptation planning in cities and local communities. Specialization will be required as climate change considerations become mandatory determinants of land use planning and urban development planning. Ideally, such specialization will occur in parallel with a continuous process of building records of tested local adaptation practices as they emerge from local governments around the world.

The first generation of adaptation tools we currently have access to are, in many cases, rather simple templates and guidance notes that have proved useful during the early days of local decision-making for adaptation. These tools need to be improved iteratively as new knowledge of adaptation practice becomes available. Future iterations of adaptation frameworks and tools will need to provide more sophisticated guidance with respect to decision-making, such as high-resolution impact modeling, adaptation cost-benefit analysis, evolving quantitative risk and vulnerability assessment techniques, as well as the integration of qualitative data on local knowledge, risk perceptions and social narratives into climate risk analysis processes.

Chapter 41
Building Resilience to Climate Change in Asian Cities

Sarah Opitz-Stapleton, Laura Seraydarian, Karen MacClune, Greg Guibert, Sarah Reed, Fern Uennatornwaranggoon, and Cristina Rumbaitis del Rio

Abstract Climate change will impact urban populations and systems over and above the existing twenty-first century challenges faced by city managers, leaders, and planners. This paper summarises the processes, methods, and tools that are currently being developed through the Rockefeller Foundation's Asian Cities Climate Change Resilience Network (ACCCRN). These tools and methods are currently being used and refined by a diverse set of stakeholders working in growing cities across Asia to improve climate change resilience. The findings are drawn from the practice and experience of actors striving to make cities resilient to climate change and climate variability.

Keywords Climate change • Local government • Resilience • Urban

41.1 Overview of the Asian Cities Climate Change Resilience Network (ACCCRN)

Cities of the future will face unprecedented challenges as a result of climate change, population growth, and rapid and poorly planned urbanisation. Poor and vulnerable populations will be the hardest hit as they have the least capacity to prepare and plan for the impacts of climate change and the least capacity to respond.

UN-Habitat estimates that 70% of the world's population will live in urban areas by 2050, and approximately 60% of this growth is expected to take place in Asia.

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Climate change will lead to warmer temperatures, greater variability in local conditions, and changes in the frequency, intensity, and location of precipitation and storms. Medium sized cities are growing particularly fast and lack the resources of larger, more established cities to address the compounding challenges of climate change, urbanization, poverty, and environmental degradation. How will these cities respond to the inevitable shocks and surprises of climate change, while assuring the wellbeing of their growing populations?

As part of a 5-year program, ACCCRN is working with rapidly urbanizing cities that have limited resources to address the compounding challenges of climate change, urbanization and poverty. It aims to catalyze attention, funding and action toward building climate change resilience by creating robust models and methodologies for assessing and addressing risk in cities. ACCCRN focuses on fast growing, medium sized cities since they are seen as having the capacity to make forward-looking investments and to integrate new thinking into city planning. Currently, ACCCRN is working in ten core cities across India, Indonesia, Thailand and Vietnam (Fig. 41.1).

It is expected that ACCCRN will achieve impact in three key outcome areas:

1. *Capacity building of cities*: Selected cities in South and South East Asia will have improved capacity to plan, finance, coordinate, and implement climate change resilience strategies. Through assistance provided by the ACCCRN program, cities will generate and test a range of actions, models and processes to build climate change resilience. Cities would employ a multi-stakeholder,

Fig. 41.1 ACCCRN core cities

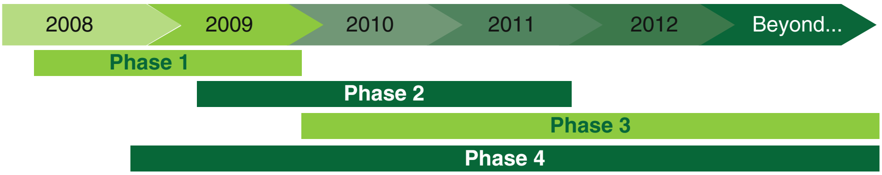

Fig. 41.2 ACCCRN timeline

participatory process to develop the human resources, knowledge, and institutions to produce and update resilience strategies that include poor and vulnerable populations.

2. *Network for knowledge, learning and engagement*: Practical and actionable knowledge generated in the program are shared and used by a broad range of representatives of cities, civil society, donors, private sector and technical partners who engage with ACCCRN. At a national, regional and global level, the ACCCRN program is linked with a growing number of networks and dialogue partners in the urban resilience space.
3. *Expansion, deepening of experience, scaling up*: Through the funding, promotion and dissemination of resilience building models generated in the program, ACCCRN will engage with potential sources of funding and technical assistance globally; new and more diverse partners provide resources and funding for replication in current and new cities to support the implementation of resilience plans and strategies.

ACCCRN is implemented by a network of partners at the country and city levels, with a range of technical support provided by international and regional partners. Throughout the various phases of the program, key city stakeholders will network across the participating cities and with national and international experts of climate science, adaptation, and disaster risk reduction. There are four phases to the ACCCRN process (Fig. 41.2):

Phase 1: City scoping and selection
Phase 2: City-level engagement and capacity development
Phase 3: Implementation of urban resilience interventions
Phase 4: Replication and scaling up

41.2 Core Themes of ACCCRN

ACCCRN partners use a core set of themes as the starting point for building adaptation and learning frameworks. ACCCRN examines the intersection of climate change, urban systems, and vulnerability to test resilience strategies by considering both direct and indirect impacts of climate change. Figure 41.3 captures the three aspects

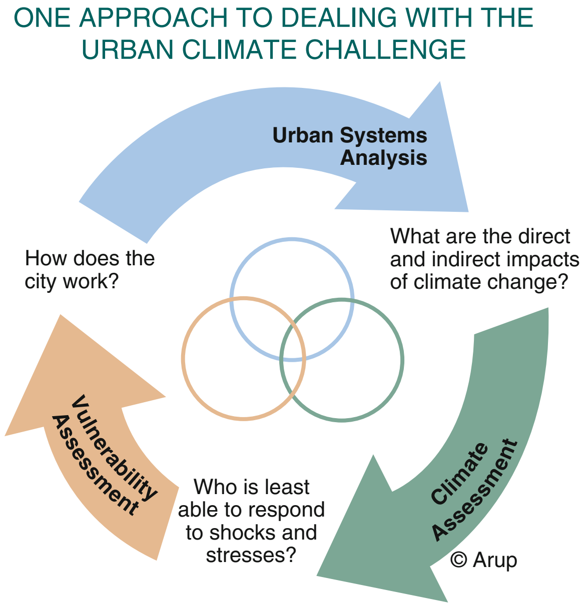

Fig. 41.3 An approach to dealing with urban climate challenge (Brown and Kernaghan 2010)

of the urban climate challenge and the questions ACCCRN partners are investigating in each city in order to identify resilience strategies, actions and plans.

Climate change: Part of building urban resilience to climate change is understanding what climate projections and historical information can and cannot say about the future. This allows for the development of adaptive solutions that do not presume a single climate future. Climate change projections are uncertain for many reasons – not the least of which being the uncertainty of what kind of energy and lifestyle choices will be made in the future. While climate projections cannot give exact estimates of how much precipitation will fall in one of the ACCCRN cities by 2050, for example, the projections provide very useful information on trend changes and ranges of climate conditions. The uncertainty of climate change projections is challenging ACCCRN cities to explore innovative actions and strategies that are capable of being resilient against a wide range of climate conditions, rather than relying on traditional approaches to planning and engineering that assume that future climate events are simply predictable reflections of historical trends. ACCCRN works with city partners to identify the broad trends and ranges of climate projections for their regions and to develop resilience strategies around multiple 'what if' climate scenarios that do not depend on precise knowledge of the future.

Urban systems and vulnerability: A city is comprised of high population densities within defined political and administrative units. Often, a local ecosystem's capacity to provide the basic food and water requirements of a city is exceeded. Urban systems, then, depend on sources of food, energy, and raw materials from elsewhere, accessed through regional, national, and global networks and markets. Cities' socioeconomic systems tend to be quite resilient because of the innovative, interlinked, and flexible systems on which they are founded. Yet cities are intricate systems whose components interact in complex and often unpredictable ways. Urban physical, socio-economic, institutional, and ecological systems can fail, and when they do, the results can be catastrophic for large populations directly and indirectly affected. The impacts of climate change may: (1) directly affect the ecosystems that produce the food and water on which cities depend; (2) have disproportionate impacts on poor and vulnerable urban populations; and (3) overwhelm the infrastructure that ensures movement of people, goods, and services.

Resilient cities: Given the current hazards that cities face and the likely impacts of climate change on climate variability and baseline conditions, what can cities do to be resilient against a variety of shocks and slow-onset changes? Resilient cities create, enable, and sustain the services and institutions required for basic ongoing survival and are characterized by their ability to generate new opportunities for their residents. They avoid relying on solutions that depend on anticipating specific hazards, and instead take a broader, integrated approach. A resilient city is able to withstand a variety of challenges because the following elements are incorporated into urban systems and the ways in which people construct and maintain those systems (Fig. 41.4):

Redundancy: Several urban systems can serve similar functions and provide substitutable services when another system is disrupted. If redundancy is eliminated, urban vulnerability increases. An example of infrastructure redundancy may be the use of multiple energy sources with a variety of pathways distributing power to all parts of the city. Redundancy can also build social

Fig. 41.4 Elements of urban resilience

capacity. For example, training individuals in dispersed neighborhoods in basic health and emergency response so that when an extreme event occurs, fragmented neighborhoods can provide immediate triage and basic medical services until transportation and communication systems are restored.

Flexibility: Resilient cities have the ability to absorb shocks and slow-onset challenges in ways that avoid catastrophic failure if thresholds are exceeded. In the event that a system or institution fails, it does so with minimal impact to other systems. Flexibility can include such things as a diversified economic base not exclusively dependent upon agriculture or a single industry, or actions like coastal ecosystem restoration to serve as a buffer against flooding, rather than relying on levies.

Capacity to Reorganize: The ability to change and evolve in response to changing conditions includes the ability to reverse processes of degradation. It also means recognizing when it is not possible to return to previous methods, with a focus on the continual effort to find new solutions and strategies to evolving challenges. This can include, for example, the capacity to introduce new structures, organizations, and land use measures in response to increased risk of bush fires around the fringes of cities during hot, dry weather.

Capacity to Learn: The ability to internalize past experience, respond to it, and avoid repeating mistakes ensures that future decisions are made with appropriate caution and forethought. This could include, for example, explicit efforts to document and integrate lessons from previous disaster management efforts into future planning or by monitoring watershed conditions to ensure adequate wetland and floodplain areas are maintained to buffer floods.

41.3 ACCCRN Methods and Tools

A common framework across the program has been adapted and implemented locally to reflect national and city contexts and expertise. While ACCCRN supports leading-edge climate resilience analysis, engaging local experts and key city stakeholders in their own language is a critical part of the process.

All aspects of the program are iterative, from developing tools and methodologies used to assess current and future urban climate vulnerability, to testing and piloting resilience strategies and actions. The Shared Learning Dialogue (SLD) process (Fig. 41.5) builds partners' capacities to:

- Deal with the uncertainty of climate projections
- Understand and work with complex, adaptive urban systems
- Generate new information and utilize multiple sources of existing information and expertise in new ways
- Engage vulnerable groups and involve them in resilience planning
- Cross disciplinary and organizational boundaries and scales of governance

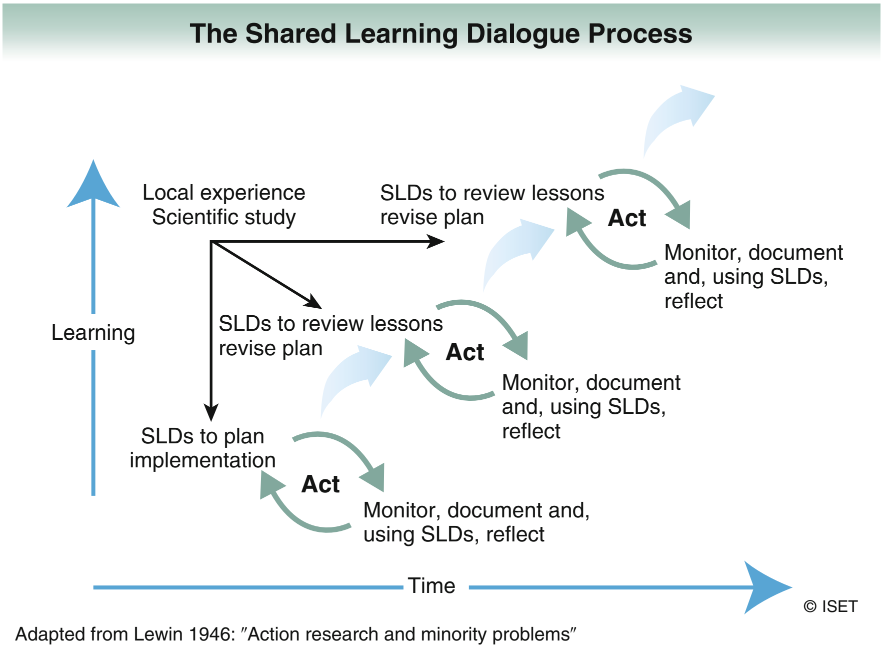

Fig. 41.5 The shared learning dialogue process

- Test and adapt tools to local conditions and capacities
- Develop new planning and learning processes suited to different city contexts and actors
- Share lessons between cities and beyond

In Phase 2, city-level engagement and capacity development, cities explore their current and future vulnerabilities, identify their most vulnerable populations, and begin to develop an urban resilience strategy and action plan. These processes are iterative. ACCCRN partners use a combination of methods and tools, centered on SLDs and climate vulnerability analyses that they have adapted to their specific city contexts. ACCCRN partners are using SLDs, piloted by the Institute for Social and Environmental Transition (ISET), to construct these city-level processes. SLDs are iterative, transparent group discussions with local actors in communities, government agencies, and specific organizations designed to bring together available information on climate change with local knowledge and perceptions. Development of a common understanding of climate change and urban resilience takes time; it requires a process in which insights from multiple sources within communities and across scales and jurisdictional boundaries can be brought together. The SLD process is designed to ensure that vulnerable populations in each city have the opportunity to build their adaptive capacity and participate in the urban climate resilience process. The ultimate outcome of the SLD process is not only a shared understanding but includes actions for responding to climate change risks. The SLD process guides all ACCCRN stakeholders in identifying the constraints and opportunities in adapting to climate change, understanding the complex systems within each of the partner cities, and working with the poor and vulnerable populations to build urban resilience. Each ACCCRN city is undertaking climate vulnerability assessments to provide a basis for better understanding of how individuals, communities, and urban systems specific to their city may be affected by future climate impacts – both directly and indirectly.

Through the climate vulnerability assessments, the cities are exploring what existing capacities can enhance their ability to adapt and be more resilient to climate change. The assessments result is vital information that feeds into the iterative SLD and resilience planning processes. They help ensure that resilience strategies, actions, and interventions will target the most vulnerable populations, address vulnerabilities of urban sectors and systems, and build on existing capacities. During the assessment phase of the ACCCRN program, there is equal emphasis on identifying local and regional capacities as on vulnerabilities. ACCCRN partners adapt existing tools and methodologies for conducting vulnerability assessments to their specific contexts; still, each climate vulnerability assessment entails:

- An understanding of projected climate scenarios and potential impacts and the limitations of the projections
- Identification of who/what are the most vulnerable groups, areas, sectors, and urban systems and how they may be affected
- Identification of the range of factors that systematically combine to make them vulnerable, including both direct (e.g. exposure to hazards) and indirect (e.g. regional or international food security) factors
- Assessment of existing capacities to adapt

41.4 Next Steps: Pilot Projects to Implementation

The ACCCRN cities use SLDs and climate vulnerability assessments to help develop resilience strategies and action plans. In the short term, cities are conducting in-depth ‘sector studies’ for deeper analysis on priority issues facing the city and testing small pilot activities to explore specific vulnerability needs or small areas in which they can begin making changes and monitoring the outcomes. Armed with knowledge of key vulnerabilities and existing adaptive capacities, and drawing on both international and local experience, the cities are developing climate resilience strategies and action plans that will enable them to better prepare for the challenges of current and future climate variability. This includes a process of identifying, assessing, and prioritizing actions that will effectively build climate resilience of the city’s systems and resilience of its poorest and most vulnerable populations. These resilience strategies and action plans will be integrated with city planning processes, but may also require additional financial and technical support from government departments, donors, private sector, and other sources. Over the next few years, cities will implement and learn from these strategies and interventions as well as monitor how effective these efforts are in strengthening resilience. Through networking and shared learning within and between cities, countries, and sectors, ACCCRN hopes to scale-up and replicate successful strategies both within and beyond the ACCCRN network.

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Chapter 42
Local Vulnerability Assessment of Climate Change and Its Implications: The Case of Gyeonggi-Do, Korea

Jaekyung Koh

Abstract This paper provides a set of vulnerability indicators appropriate for municipalities and gives the results of their application to 31 municipalities in Gyeonggi-Do, the largest provincial government in Korea. The vulnerability assessment aims to identify relative vulnerability across municipalities. Expert consultations and the Analytic Hierarchy Process (AHP) was used to derive indicators and determine their weightings. The definition of vulnerability developed by the IPCC was used, which consists of three components – exposure, sensitivity and adaptive capacity. The vulnerability indices are composed of 3 categories, 11 sectors, and 35 indicators. The results of the AHP reveal that the weighting of adaptive capacity is highest, followed by sensitivity and then climatic stimuli in order of significance. The most vulnerable areas include Yeoju, Yangpyeong, Gimpo, Pocheon, Yeoncheon, and Hanam, which have higher sensitivity and lower adaptive capacity to climate change. The analysis shows that vulnerability indices are correlated negatively with economic capacity and positively with natural hazard damages. The results of the vulnerability assessment indicate the need for a differentiated approach to adaptation based on the local characteristics of the sectors. The study should be considered a first step in understanding vulnerability to climate change. A regional climate model and data collection system for vulnerability assessment should be developed. The indicators could be replicated for other local governments.

Keywords Adaptation • Climate change • Local government • Vulnerability indicators

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42.1 Introduction

Adaptation requires a bottom-up approach because climate impacts and vulnerability are location specific. When climatic events occur, their impacts may differ depending on a region's physical infrastructure, social capital, and specific geographic and demographic characteristics. Adaptation involves both the reduction of climatic impacts and the enhancement of adaptive capacity. Given limited resources, then, it is important to identify particularly vulnerable areas in order to set priorities for adaptation measures (UNDP 2005; Snover et al. 2007; UKCIP 2003).

The Korean municipal government's attention to climate change, which has a mere 3–4 year history, has focused solely on mitigation. Recently, though, the central government has supported local governments in developing adaptation strategies. However, the methodology and infrastructure for local vulnerability assessment is not sufficient. This study aims to help local governments find a strategic entry point by developing vulnerability assessment indicators and by assessing relative vulnerability at a local level. The next section of this paper presents types of vulnerability assessment and reviews the related literature. Following this, the third section introduces a set of indicators for local vulnerability assessment and sets out the methodology used in this study. The fourth section describes the estimated vulnerability indices as they are applied to 31 municipalities in Gyeonggi-do. The final section offers suggestions for the use of the indicators in developing adaptation policies.

42.2 The Concept of Vulnerability and the Purpose of Vulnerability Assessment

42.2.1 The Concept of Vulnerability to Climate Change

In the study of climate change, the concept of vulnerability is often divided into 'starting-point' and 'end-point' (Füssel 2007). The former may also be referred to as 'pre-vulnerability' and the latter as 'post-vulnerability.' The major goal of the first perspective is to reduce the socio-economic vulnerability inside a system. Kelly and Adger (2000) define vulnerability as 'the ability or inability of individuals or social groupings to respond to, in the sense of cope with, recover from or adapt to, any external stress placed on their livelihoods and well-being.' They also use the term 'social vulnerability' to emphasize the social level that has been neglected in the study of natural disasters and adaptation so far. Blakie et al. (1994) also divide vulnerability into the bio-physical level and social level. Vulnerability is the 'starting-point' of assessment because it is determined by an individual or social group's capacity to handle stress, that is, its adaptive capacity. Vulnerability as an 'end-point,' on the other hand, relates to the residual impacts that follow the implementation of adaptive measures. The IPCC's definition represents vulnerability as a function of exposure, sensitivity of a system, and adaptive capacity (McCarthy et al. 2001). This means that the residual impacts after the adaptation process determine the level of vulnerability. This paper adopts the IPCC's concept of vulnerability as a function of both potential impacts from climate change and adaptive capacity. The starting-point approach is also taken because the vulnerability assessment is based on present vulnerability.

42.2.2 The Types and Objectives of Vulnerability Assessment

Clarifying the purpose of vulnerability assessment is essential as the methods used, the information required, and the uncertainty involved can differ depending on whether the objective is to (1) set up a long-term greenhouse gas reduction goals, (2) investigate vulnerable regions or sectors, or (3) develop adaptation strategies (Füssel and Klein 2006; Burton et al. 2002; Patt and Schröter 2009).

Table 42.1 describes the varying objectives of climate change vulnerability assessment. The similarities among each include climate impact assessment, investigation of vulnerable sectors and regions for resource distribution, and analysis of

Table 42.1 Objectives of vulnerability assessment

Research	Vulnerability assessment objectives
Burton et al. (2002)	Impact assessment to establish long-term goal for reducing greenhouse gas emissions
	Development of adaptation policy
Smith and Wandel (2006)	Estimation of climate impact
	Development of adaptation policy and alternatives
	Comparison of vulnerability across nations, regions, and communities
Patt and Schröter (2009)	Climate change impact assessment to develop framework for reducing greenhouse gas emissions
	Improvement of adaptation
	Addressing social inequality
	Science research
Patwardhan (2006)	Data collection and analysis for climate impact assessment
	Estimation of cost and damage by climate impact
	Establishing adaptation policy to decrease damage level
	Prioritization of researches
	Setting priorities in adaptation policies through effective distribution of resources
Füssel and Klein (2006)	Climate impact assessment for reduction of greenhouse gas emissions
	Socio-economic vulnerability assessment for reduction of greenhouse gas emissions
	Resource distribution through investigating vulnerable sectors and regions
	Development of adaptation policy

adaptation options to develop adaptation policy. Climate change vulnerability assessment involves both the analysis of various impacts of climate change on specific systems as well as suggestions of policy options for minimizing risk. It therefore transforms from bio-physical impact assessment to more composite assessment.

42.2.3 Literature Review

Comparative studies of vulnerability across nations using climate change assessment indicators have been carried out by Moss et al. (2001) and Brooks et al. (2005). There are two types of local climate vulnerability assessment studies. The first uses indicators representing physical vulnerability and adaptive capacity, and presents vulnerability maps or vulnerability indices (Cutter et al. 2000; Parkins and MacKendrick 2007; Sullivan and Meigh 2005; Wall and Marzall 2006; O'Brien et al. 2004; Preston et al. 2009). The second type involves the qualitative analysis of climate change impacts using a matrix or participatory process (Snover et al. 2007; Blakely 2007; van Aalst et al. 2008).

Meanwhile, as Han et al. (2005, 2006, 2007) and Yu et al. (2006) show, most domestic climate change studies concentrate on sectoral climate change impact assessments while few studies about vulnerability assessment exist. Local vulnerability assessments were conducted by Ahn (2007) and Yu et al. (2008) using indicators. The latter study has particular significance as it was the first to comprehensively assess the characteristics of climate change vulnerability across 16 provinces and metropolitan cities in Korea.

Still, studies about vulnerability assessment for municipalities have rarely been conducted in Korea. This paper examines relative vulnerability among municipal governments, and provides a comprehensive assessment of exposure, sensitivity and adaptive capacity in 31 municipalities of Gyeonggi-Do, the largest provincial government in Korea.

42.3 Methods of Vulnerability Assessment

42.3.1 Outline for Case Study

With a population of 11,600,000, Gyeonggi-Do accounts for 23.3% of the total population of Korea. The province is 17 times larger than that of Seoul, taking up 10.2% of the national territory. The population density, however, is only 5% of Seoul. While multiple environmental regulations are imposed within the province to protect the water resources of the Pal-Dang Dam, it remains one of the fastest

Fig. 42.1 Location of Gyeonggi-Do and 31 municipalities

growing provinces, the population and economy under high development pressure. With a relatively low population density and large area, Gyeonggi-Do shows local differences in its social, economic and environmental characteristics (Fig. 42.1).

42.3.2 Vulnerability Indicators

The IPCC defines vulnerability as a function of exposure, sensitivity, and adaptive capacity. These three components are the key factors in determining a system's vulnerability to climate change and provide useful information for assessing and reducing climatic threats (Fig. 42.2).

Exposure: Climate exposure indicators include temperature rise, heavy rain, drought, and sea level rise. The IPCC predicts that global warming will continue as severe heat waves, heavy rain, drought, tropical depression and sea level rise increase in probability (Parry et al. 2007). Significant temperature rise and an increase in precipitation intensity have been observed in Gyeonggi-Do (Koh et al. 2008). In addition, some cities situated near the West Sea are expected to be affected by sea level rise.

Sensitivity: The degree of a system's sensitivity to climatic hazards depends not only on geographic conditions but also socio-economic factors such as population and infrastructure. Indicators of sensitivity can encompass geographical conditions, land use, demographic characteristics, infrastructure and industry. Indicators for physical infrastructure, institutions, and policy options that reduce vulnerability are included in adaptive capacity.

Adaptive capacity: Adaptive capacity describes the ability of a system to cope with climatic extremes. This can be determined through, for example, economic

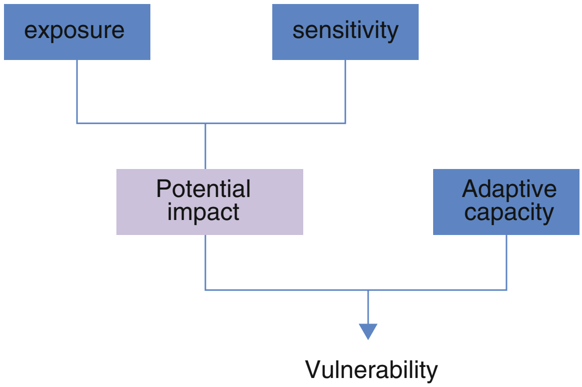

Fig. 42.2 Components of vulnerability

resources, systems of local food supply and distribution, early warning systems, governance, accessibility of information, and crisis management programmes and policy (McCarthy et al. 2001). More comprehensively, adaptive capacity involves accessibility to political power, specific beliefs and customs (Cutter et al. 2000), technological alternatives, human resources and social capital (Yohe et Tol 2002). Generally speaking, adaptive capacity to climate change depends on economic resources, access to technology and information, varieties of infrastructure, institutional capability, and the fair distribution of resources (Ormond 2004:11).

Adaptive capacity indicators compose economic capability, physical infrastructure, social capital, institutional capacity, and data availability. Economic capability represents the economic resources available to reduce climate change vulnerability. Physical infrastructure describes the hardware available to enhance adaptive capacity. Indicators of social capital include governance to climate change, citizen actions, and the coping ability of citizens. Institutional capability is represented by political leadership, disaster prevention systems, and climate change policy.

42.3.3 Data Collection and Methods

Table 42.2 shows the vulnerability assessment indicators used in this study. Climate data was collected between 1999 and 2008 by the Central Meteorological Office, the Automatic Weather Station and by precipitation observatories. For municipalities without any observations, data of neighboring areas were substituted, and observations with missing data or outliers were excluded. Figures 42.3 and 42.4 show selected weather and precipitation observations.

Sensitivity and adaptive capacity indicators were measured using statistical data. Survey data from Koh et al. (2008: 156) were also used for some adaptive capacity

Table 42.2 Vulnerability indicators

Category	Sectors	Indicators	Proxy variables	Function of vulnerability
Exposure	Precipitation			
	Heavy precipitation	Heavy precipitation frequency	Number of days with precipitation ≥80 mm/day	+
		Maximum 1 day precipitation	Maximum 1 day precipitation	+
		Precipitation intensity	Annual total precipitation/number of days with precipitation ≥1 mm	+
	Drought	Consecutive dry days	Average of consecutive dry days	+
		Maximum consecutive dry days	Maximum number of consecutive dry days	+
	Temperature	Tropical nights	Number of days with daily minimum temperature ≥25°C	+
		Heat wave	Days with daily maximum temperature ≥33°C	+
		Heat wave duration index	Maximum period >5 consecutive days with Tmax >5°C above the past 30 years daily Tmax normal	+
	Sea level rise	Sea level rise	Affected area presumed by 1m sea level rise	+
Sensitivity	Geography/land use	Ecologically sensitive area	Habitat of endangered species	+
			Tidal wetland areas	
		Drought vulnerable area	Agricultural land area/total land area	+
		Flood risk area	Flood risk area/total land area	+
			Utilized river bed area/total land area	
		Low-lying coastal area	Proportion of areas at altitude below 1 m	+
	Population characteristics	Population density	Number of population/total land area	+
		Old age population	Proportion of population aged over 65 years	+
		Socially vulnerable groups	Proportion of elderly living alone	+
			Proportion of people in poverty	
		Climate related disease patients	Proportion of patients with respiratory diseases	+
			Proportion of patients with vector-borne diseases	

(continued)

Table 42.2 (continued)

Category	Sectors	Indicators	Proxy variables	Function of vulnerability
	Infrastructure/industry	Infrastructure	Proportion of transportation and supply facilities area	+
		Industrial park	Proportion of industrial park area	+
		Building	Proportion of housing units older than 30 years	+
Adaptive Capacity	Economic capability	GRDP	GRDP	–
		Economic growth	GRDP growth rate during 5 years	–
		Fiscal independence	Local tax+ non tax revenue/general account budget	–
	Physical infrastructure	Open space	Park area per capita	–
		River improvement	River improvement length (km)/improvement needed length (km)	–
		Medical facility	Total population/hospital beds	–
			Medical employees/total population	
			Public health centre employees/total population	
			Number of general hospitals	
		Access to clean water	Drinking water supply rate	–
			Sewage treatment system supply rate	–
			Use of groundwater/available groundwater	+
		Communications	Cellular phones per household	–
			Ratio of PC supply and use	
			Internet subscription rate	
	Social capital	Public-private partnership	Climate change partnership	–
		Citizen's capacity on climate change	Citizen's actions on climate change	–
			Education and campaign for disaster management	
			Proportion of people who took health education	
		Sense of community	Proportion of volunteers	–
			Local voluntary commitment for disaster management	

Institutional capacity	Political leadership	Political leader's concern in disaster management	–
		Political leader's concern in climate change	
	Prevention system	Delivery system for disaster relief	–
		Warning system management	
		Disaster prevention system management	
	Staff for adaptation measures	Public officials per capita	–
		Convalescence care	+
	Policy level	Level of climate change policy	–
		Climate change policy system	
		Level of disaster management policy	

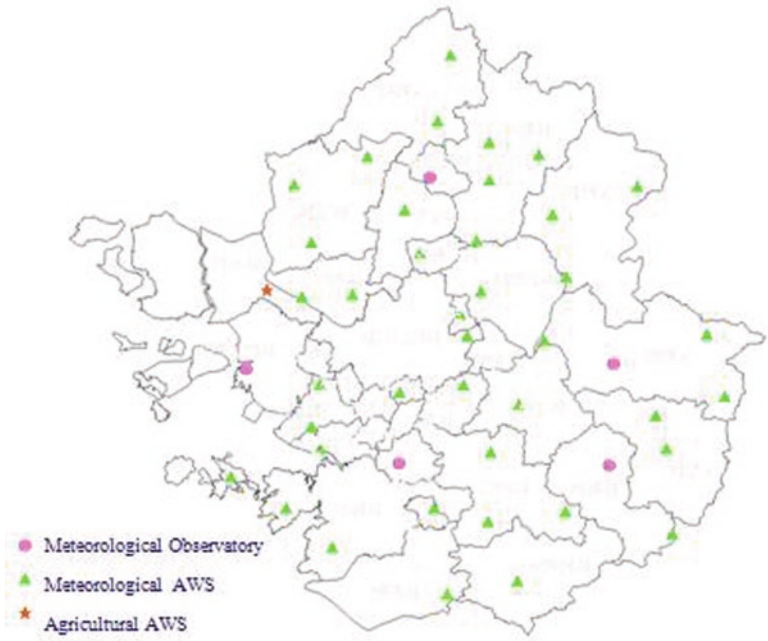

Fig. 42.3 Weather observations

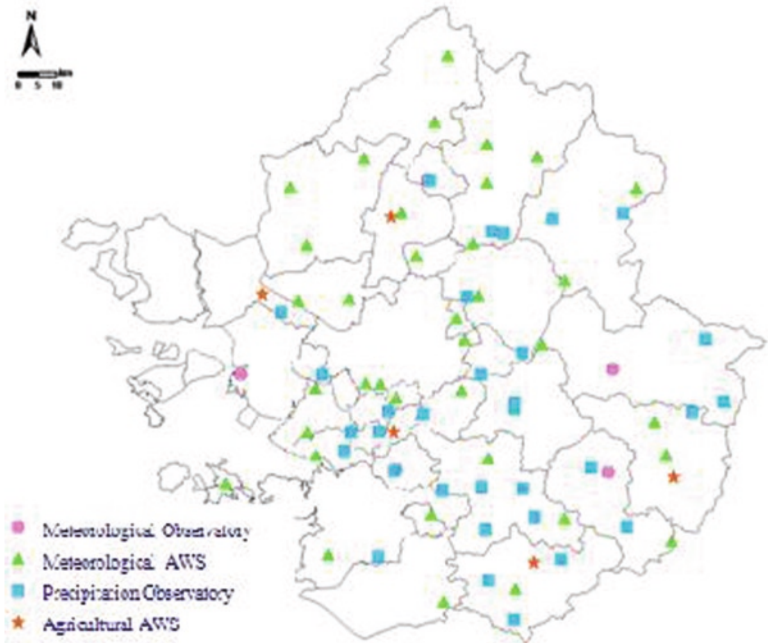

Fig. 42.4 Precipitation observations

indicators, such as climate change partnerships, citizen action, and political concern and leadership. Data for prevention systems and disaster management related indicators were derived from the results of disaster management evaluation. Two experts meetings and an interview with public officials were conducted to develop and select vulnerability indicators. Vulnerability indices were estimated by applying the weighting drawn through AHP analysis after standardizing each proxy variable. The results were then illustrated in a GIS map.

42.4 The Results and Characteristics of Vulnerability Assessment

42.4.1 The Results of Vulnerability Assessment

The cities with the highest exposure indices are in northern Gyeonggi-Do, which includes the cities of Goyang, Gwangju, and Gapyeong. Sensitivity indices are high in areas such as Pyeongtaek, Gimpo, Osan, Yeoncheon, Paju, Goyang. In Sungnam, Anyang, Bucheon, Gwangju, Uiwang, Gwacheon, sensitivity is relatively low. The impact index, numerical average of exposure index and sensitivity index is high in Gimpo, Goyang, Osan, Yeoncheon, Paju and Pyeongtaek, while Bucheon, Sungnam, Uiwang, Anyang, Gwacheon and Suwon demonstrate low impact indices. High adaptive capacity is represented in Gwacheon, Pyeongtaek, Suwon, Yongin, Anyang, and Ansan, while low in areas like Yeoju, Yangpyeong, Dongducheon, Hanam, Pocheon, and Gimpo (Figs. 42.5 and 42.6).

Figure 42.7 demonstrates the distribution of the composite vulnerability indices across municipalities. High vulnerability is shown in areas like Yeoju, Yangpyeong, Gimpo, Pocheon, Yeoncheon and Hanam. Most of the areas in this group show high climate exposure and sensitivity, which means that risk from the potential impacts of climate change is high, and adaptive capacity to reduce vulnerability is low. On the other hand, the areas such as Gwacheon, Suwon, Anyang, Sungnam, Bucheon and Gunpo with low impact and high adaptive capacity show the lowest vulnerability. Generally, the northern part of Gyeonggi-Do is more vulnerable to climate change compared with the southern part (Fig. 42.7).

42.4.2 The Validity of Vulnerability Indices

In order to verify composite vulnerability indices, this study investigated the relationship between vulnerability indices and natural hazard damage such as the disaster damage rank of municipalities, disaster indices (Shim et al. 2008), and the amount of disaster damage over the past 10 years. Regression analysis shows that as the disaster damage scale or index gets higher, the vulnerability index also gets higher – the value of the coefficient, then, shows positive (+). On the other hand, as

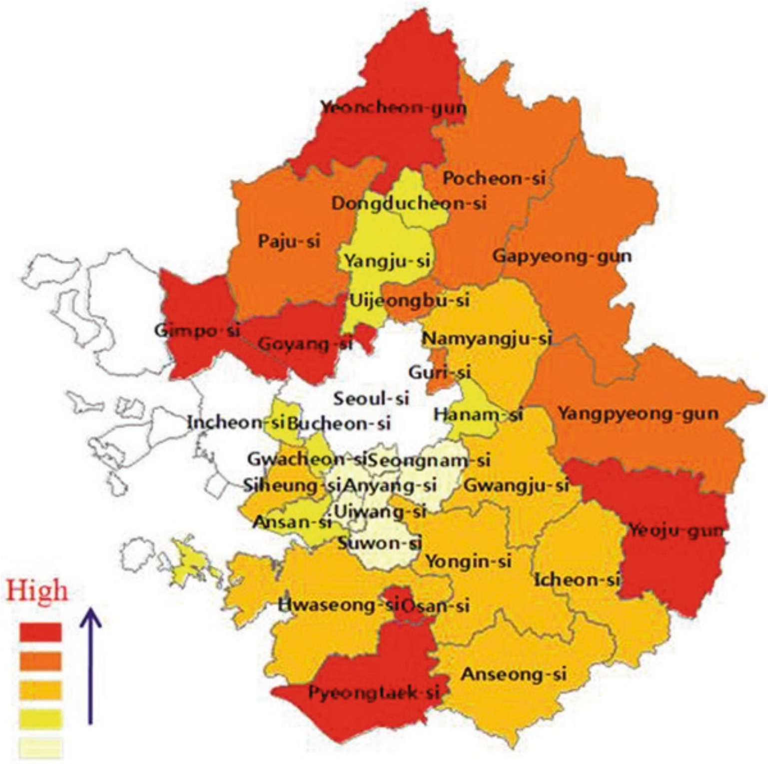

Fig. 42.5 Climate impact map

economic capability increases, vulnerability decreases, and adaptive capacity and vulnerability indices show a negative relationship. All the values of regression coefficients from four regression formula are statistically significant (with $p < .01$).

42.4.3 Types and Characteristics of Vulnerability

Figure 42.8 illustrates the distribution of vulnerability types across municipalities according to potential impact and adaptive capacity. Vulnerability depends on the characteristics of a system or its adaptive capacity even if similar climate extremes like flood or drought happen. Naess et al. (2005), examining two areas in Norway, shows that the level of adaptation policy differs depending on the change in a system, the power structure surrounding policy options for flooding, and social learning from experience with flooding.

Type 1 shows areas with high vulnerability to climate change impacts and low coping ability due to a lack of resources and manpower. Type 2 shows the areas

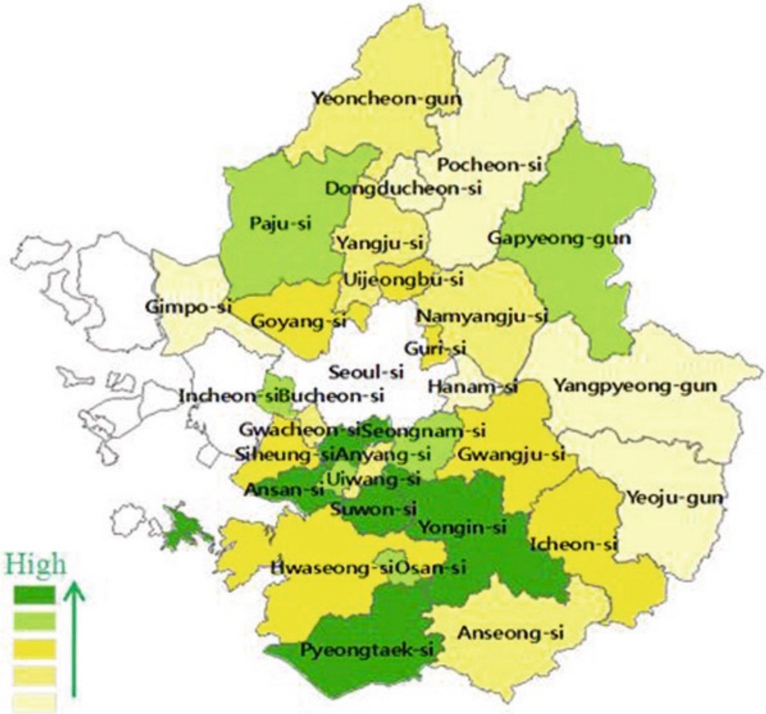

Fig. 42.6 Adaptive capacity map

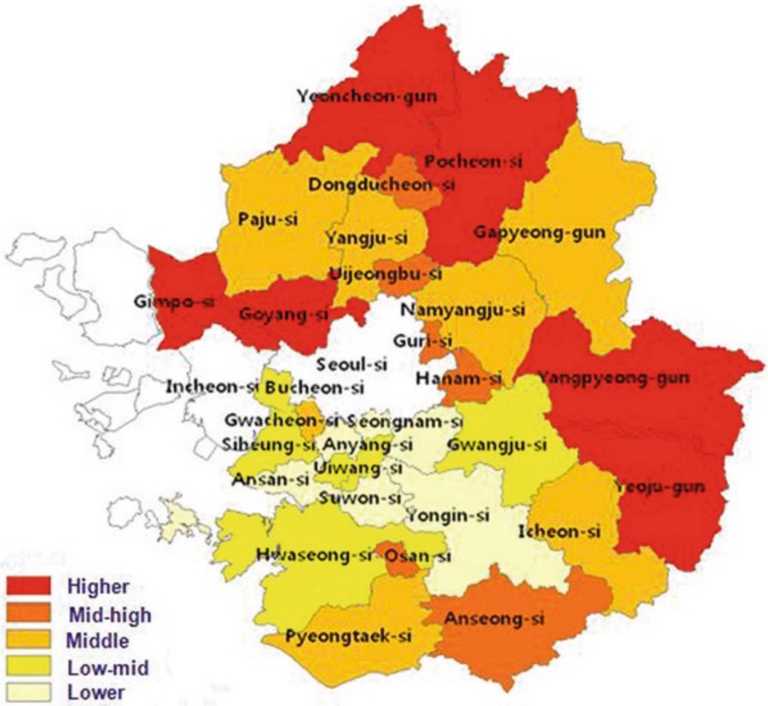

Fig. 42.7 Vulnerability map

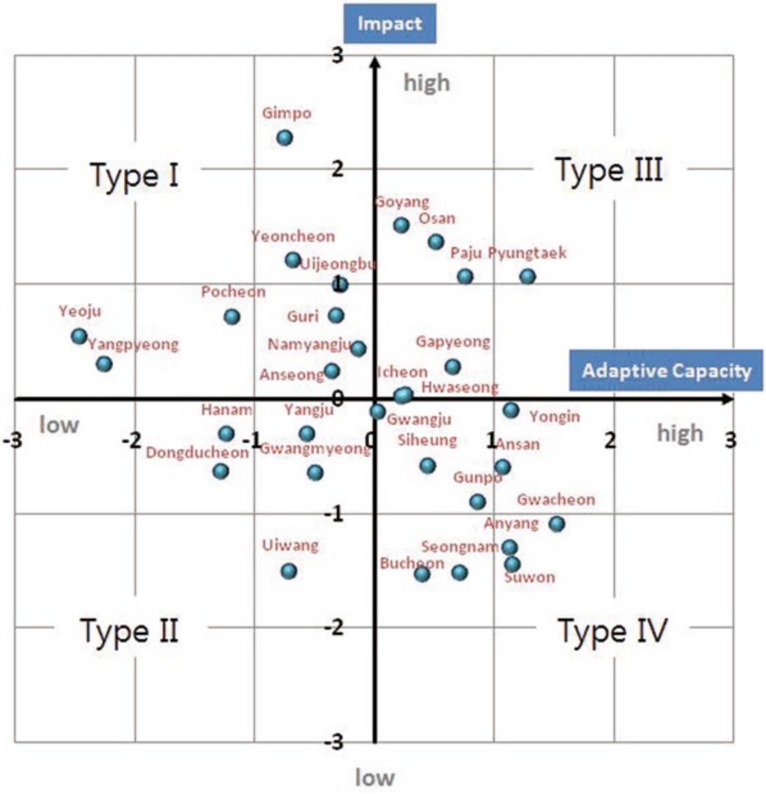

Fig. 42.8 Vulnerability types and characteristics

where climate change impact is not high, but adaptive capacity is low. These areas are exposed to residual impacts (UNDP 2005: 76). In some cases, vulnerability is worsened by implementing the wrong policies (Briguglio 2008). Type 3 indicates the areas that are endogenously influenced by climate change, but whose risks can be reduced to some extent because of high adaptive capacity. Type 4 is the most desirable scenario with little climate change impact, high adaptive capacity, and the lowest vulnerability.

42.5 Conclusion and Suggestions

The composite vulnerability assessment through the use of indicators provides a tool to evaluate the comparative distribution of vulnerability to multiple stresses at the local level (O'Brien et al. 2004:312). Mapping vulnerability is useful to conduct comparative assessment across regions and to prioritise cities or sectors for adaptation policy intervention.

The methodology also provides information on detailed indicators composing vulnerability. Even if vulnerability levels are similar, vulnerability types and characteristics may differ depending on potential climate change impacts and adaptive capacity. It is therefore necessary to differentiate the adaptation strategies and approaches according to geographic conditions, land use, demographic characteristics, economic capability, and institutional capacity of each specific region.

The results of AHP analysis demonstrate that adaptive capacity is the most important factor in adaptation at the local level, while exposure shows the least weighting. The focus of adaptation policies, then, should be directed towards developing human, physical and social capital. Policy options and institutional capability should also be improved, as well as information provision, education and campaigns within local communities. Establishing warning systems are also useful for decreasing vulnerability within budget constraints.

Vulnerability assessment indicators are useful for both monitoring adaptation and mitigation policy. Regulations on land use, sustainable sewage and water recycling systems, enlarged open spaces, design of climate change resistant buildings, creation of ecologically resilient landscapes, and enhanced monitoring are all recommendable adaptation measures. Each contributes to decreasing vulnerability as well as greenhouse gas emissions by reducing energy demand and saving resources. Moreover, mapping vulnerability is a useful communication tool to identify adaptation issues and integrate local knowledge.

Mostly statistical data were used for quantification, though for some indicators representing adaptive capacity, qualitative survey data were used. Further studies are necessary to validate whether the results of quantitative vulnerability assessment correspond with the actual vulnerability in the region. This study was potentially limited by analysing past climatic patterns on the assumption that these patterns would continue in the future. Therefore, vulnerability assessment methodologies need to be complemented by using climate prediction modelling in reflecting local climate change impacts. As the composite indices are limited in reflecting various sectors, it is recommendable to utilize more specified sectoral vulnerability indicators to monitor the effectiveness of adaptation strategies.

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Chapter 43
Ecosystem-Based Adaptation in the Urban Environment

Gabriel Grimsditch

Abstract Healthy ecosystems provide vital services for urban centres as well as for adaptation of urban communities to climate change. This paper will describe the value of ecosystem services and ecosystem-based adaptation for urban centres, giving examples of the effectiveness of this approach. It also provides possible policy recommendations for urban planners and local governments.

Keywords Climate change • Coastal cities • Ecosystem-based adaptation

43.1 Ecosystem-Based Adaptation in the Coastal Urban Environment

Cities are dependent on services provided by ecosystems both within and outside of their political boundaries. Wetlands, forests and other ecosystems can provide vital services such as sewage treatment, water purification, peri-urban agriculture, rainwater discharge, air filtering, tourism and recreation values, noise reduction or micro-climate control, among others (see Fig. 43.1 for a summary of ecosystem services by the Millennium Ecosystem Assessment). However, the ‘ecological footprint’ of a city, that is the area of land needed to provide a city with the resources it requires to function and remove its wastes, is often much greater than its own area and can contribute to degradation of the very ecosystems it relies on. For example, urban demands for seafood can affect fish stocks and

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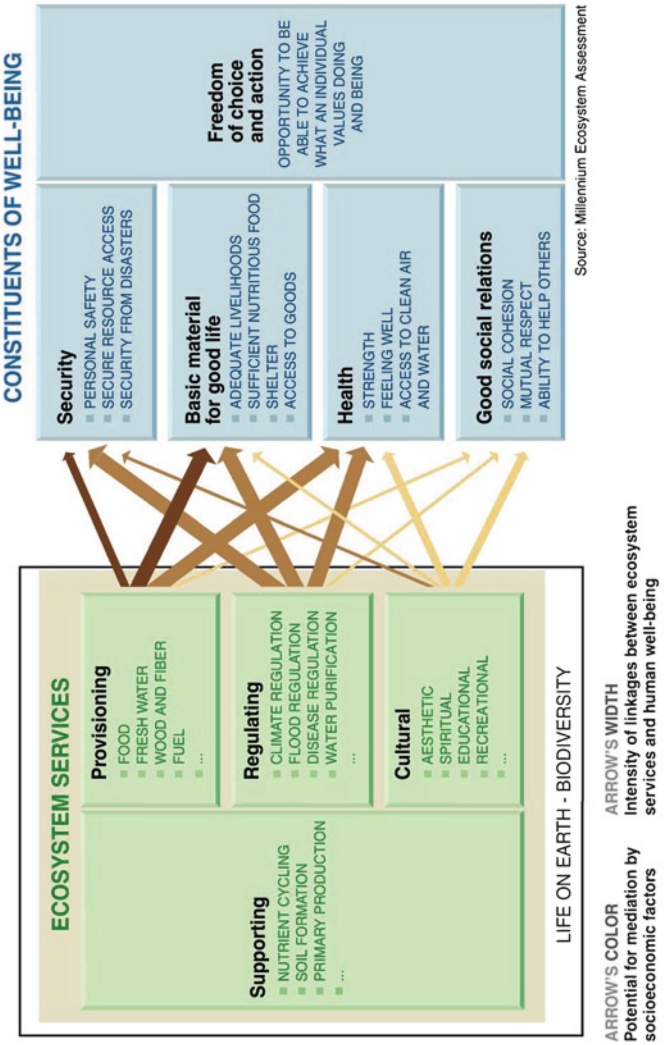

Fig. 43.1 Relationships between ecosystem services and human well-being (Source: Millennium Ecosystem Assessment 2005)

marine ecosystems thousands of kilometers away. Or the demand for charcoal can threaten forest ecosystems that are important water catchments and purification systems for cities, such as the case of Nairobi, Kenya and the Mau Forest. Another example of the importance of ecological services and the dangers associated with degraded ecosystems is Shenyang in China, where the degradation of drylands surrounding the city have increased the level of airborne particulates, threatening public health and creating constant smog over the city. These are several of many examples illustrating importance of ecosystem services for the urban environment, and the dangers associated with an unsustainable ecological footprint. Coastal cities are no exception, with many coastal ecosystems being critical to human well-being.

Since the mid 2000s more than 50% of the earth's population has settled in cities, towns and urban settlements. Population densities are highest in coastal areas, with approximately 150 million people living in locations within 1 m of the high tide level; 250 million live within 5 m of high tide. Occupying marginal lands, some of the world's poorest live in marginal urban areas, close to beaches vulnerable to flooding and erosion, near sites prone to landslides, or close to polluted land or unstable structures easily destroyed in the instance of an extreme weather event. These people are extremely vulnerable to climate change, and it is imperative to assist urban centres to adapt to these changes and protect them from risks in an effective, sustainable and cost-effective manner.

43.2 Managing Adaptation

Traditionally, the management approaches to highly vulnerable coastal cities have focused on land use planning and urban design. Coastal vulnerability and adaptation assessment methods and tools, utilised through the national communication process to the United Nations Framework Convention on Climate Change (UNFCCC) focus on establishing the current physical condition of the coast, considering the variability of each condition with changing natural environmental factors, and evaluating the likely responses. Outcomes from these and similar assessments include incorporating options such as retreat, defence, accommodation or coastal land buy-back, into urban planning policies.

More recently, there has been a movement in coastal vulnerability and adaptation towards complementing specific tools with the application of broader vulnerability and adaptation frameworks, incorporating local-scale, bottom up participatory approaches. Experience gained from previous experiences with disaster risk reduction emerging from events such as the Asian Tsunami in 2004 or Hurricane Katrina in 2005 suggests that practical support for officials charged with ecosystem management (with respect to ecosystem service provision) is far less developed than that for urban planners.

Coastal and marine ecosystems provide critical services as natural buffers to existing climatic events, helping to reduce the severity of impact on coastal cities from such events. It is widely recognised that such ecosystem services will be critical in reducing climate change vulnerability in the future. It is also important to stress that in addition to the vital provision of disaster risk reduction services, coastal ecosystems within, or adjacent to, urban settings are critical factors in establishing sustainable livelihoods. Therefore, ensuring a holistic assessment of ecosystem services to enhance resilience to climate change is an essential component of the adaptation process, particularly for highly vulnerable coastal cities.

43.3 Climate Change, Coastal Cities and Coastal Ecosystems

The effects of climate change are altering and damaging marine and coastal ecosystems around the world. Sea-level rise, erosion, increased severity of storms and flooding, ocean acidification and coral bleaching are already causing ecological devastation to coasts across the globe. This affects the livelihoods of coastal urban populations that depend on the services provided by these ecosystems, as well as the buffer that they offer to people from extreme weather events. Critical ecosystems such as mangroves, sand dunes or coral reefs create natural buffers from the effects of sea-level rise, erosion and storm surges, and can provide cost-effective adaptation options for coastal populations as well as providing multiple other ecological benefits such as food security from fisheries, medicinal value or carbon sequestration. Examples of coastal ecosystems that are integrated into urban planning for protecting coastal cities from sea-level rise and storm surges are sand dune ecosystems around the city of Cape Town, South Africa (more on this below), sand banks example is Walvis Bay, Namibia, mangroves in Sorsogon, Philippines, and among many others.

43.4 Ecosystem-Based Adaptation

Ecosystem-based management and restoration of ecosystems represents a valuable, yet under-utilized approach for urban planners grappling with adaptation to climate change. It can replace or complement other adaptation activities such as constructing costly hard infrastructure, such as sea-walls and dykes. Instead, ecosystem-based adaptation values and utilizes ecological services and biodiversity for adaptation purposes. It is also a highly cost-effective approach. The work of the Red Cross rehabilitating mangroves in Vietnam serves as an example: with an investment of US$1.1 million, nearly 12,000 ha of mangroves in Vietnam were restored, saving an estimated US$7.3 million per year in dyke maintenance (Reid and Huq 2005) while providing ecosystem services such as physical protection to coastal communities, productive fisheries and carbon sequestration.

43.4.1 A Case Study – Cape Town

A good example of using protective ecosystem services as part of a climate change adaptation plan for a coastal city comes from Cape Town in South Africa. The City of Cape Town administers approximately 307 km of coastline, its greatest socioeconomic asset. In October 2003, Cape Town formally adopted a Coastal Zone Management Strategy with the intention of managing and protecting the range of social and economic opportunities offered by the coast. The City's coast also supports a wide range of species, ecological systems and ecological services. However, sea level rise and an increase in the intensity and frequency of storm events are predicted to have significant impacts on the Cape Town coastline. Several infrastructural approaches such as sea-walls were built in order to address this threat. However, a report by the Stockholm Environment Institute (Cartwright et al. 2008) found that 'there is a growing acknowledgment within the City of Cape Town (and elsewhere) that many of the infrastructural approaches that have been used to prevent the sea from advancing in the past have proven to be costly to maintain and sometimes ineffective. In addition, such efforts, by creating a false sense of security, often come at the expense of more appropriate social and institutional responses.' Some of the more appropriate ecosystem-based responses that are now being employed in Cape Town include:

a. protection and rehabilitation of Ramsar-designated wetlands around Cape Town that absorb large volumes of advancing water and dissipate wave energy;
b. protection and rehabilitation of sand dunes (Blaauwberg, Milnerton, Hout Bay, parts of Fish Hoek, Strand for example) from physical construction and sand mining, in accordance with the City's Coastal Development Guidelines. Coastal dunes are being threatened by restriction to the movement of sand from the inner flats and rivers (by dams and weirs) as well as disruption to tidal transport of marine sand that would normally replenish these dunes. Cape Town's dunes are thus cut off from their normal source of sand and need human management if they are to continue to provide their protective services to the city. Where dunes are restored and dune grass is successfully established this vegetation is able to retain sand and support the dune. In Hout Bay, a sea-wall was even dismantled and replaced with the more sustainable option of a restored sand dune.
c. the protection of kelp beds that also play a major role in dissipating wave energy during storms.

Using ecosystem approaches for climate change adaptation is described as 'more natural, less likely to produce adverse consequences and more cost effective than most physical options' (Cartwright et al. 2008). Urban planners should be well aware of the ecosystem services available to their city when planning for climate change adaptation, and Cape Town is an excellent example of this in a coastal setting.

Despite the shift towards ecosystem approaches, sea walls are still the most common form of protection around Cape Town, yet these walls have to be regularly repaired following high tides and storm surges. For example, in 2008 the city spent 12.5 million South Africa Rand (about US$1.7 million) repairing a sea-wall at Sea Point, and this type of expensive repair will probably become more frequent as sea-levels rise and storm surges increase in intensity. Another example of a badly planned and poorly located sea-wall is at the Strand beach, where the wall is in a constant state of collapse and therefore inefficient in protecting the coast from erosion (Cartwright et al. 2008). In another setting, a review of coastal defenses of the United Kingdom showed that in 38% of locations sea-walls reduced flooding and erosion risk while 18% of the time they actually increased flooding and erosion risk (UK Department of Trade and Industry 2004).

Additional physical engineering solutions that are currently being used to protect coastal cities have also been found to have flaws. In addition to being very costly, raising infrastructure poses the challenge of estimated necessary heights to ensure safety. Additional challenges revolve around their efficiency in the long term. Revetments, rock armour, dolosse and gabions have limited lifespans and are easily damaged during storm surges. For example groynes (wooden, concrete or rock barriers perpendicular to the sea) can prevent longshore drift and erosion, but are ineffective against sea-level rise and storm surges. According to future sea-level rise scenarios, barrages, to be opened during low risk periods (to allow passing of ships and marine life) and closed during high risk periods, would have to be closed most of the time. Artificial offshore reefs can damage existing reefs and coastal vegetation, as well as alter near-shore currents and affect sea traffic.

Finally, some existing solutions do not address underlying problems but operate as disaster relief. For example, London in the UK, Maryland in the USA and Rotterdam in the Netherlands actively pump sea water out during flooding episodes. Beach drainage systems that lower water levels beneath the beach and causes sand accretion are used in Europe, USA, Malaysia and Japan, yet they can accelerate salinization of groundwater. Unfortunately, the physical engineering solutions described are either potentially inefficient or actually accentuate the impacts of sea-level rise. Urban planners are thus advised to fully assess the ecosystem services available to their cities and how to best incorporate them into climate change adaptation strategies.

43.5 Ecosystem-Based Adaptation and Other Ecosystem Services

Well-designed management schemes of coastal vegetated ecosystems can also contribute to climate change mitigation by reducing carbon emissions from ecosystem loss and degradation as well as enhancing carbon sequestration. A recent UNEP report stated that 55% of atmospheric carbon captured by living organisms is captured by marine organisms, and of this between 50% and 71% is captured by the ocean’s vegetated habitats (e.g. mangroves, salt marshes, seagrasses) which cover less than 0.5% of the seabed (Nellemann et al. 2009). These ecosystems are often found around coastal cities, and therefore effective management can contribute to both adaptation and mitigation objectives for the city. Marine ecosystems also provide food security and revenue from tourism for city dwellers. For example, fish (including shellfish) provide essential nutrition for three billion people and at least 50% of animal protein and minerals to 400 million people in the poorest countries. Over 500 million people in developing countries depend, directly or indirectly, on fisheries and aquaculture for their livelihoods (FAO 2009). Coral reef ecosystem services, including tourism, coastal protection and fisheries, are estimated to be worth US$30 billion per year (Cesar et al. 2003).

Unfortunately, these valuable coastal ecosystems are being lost at an incredible rate. Mangroves, seagrasses and saltmarshes are being lost at a rate of 2–7% annually, a sevenfold increase compared to only 50 years ago (Nellemann et al. 2009). The main reasons identified for habitat loss include unsustainable resource usage and harvesting, poor watershed management, poor coastal development practices and poor waste management in conjunction with storms surges that are increasing in frequency and intensity. The ecological footprint of coastal cities is a major factor in habitat loss and degradation.

43.6 The Policy Context

While it is widely recognized that healthy and well-managed ecosystems are valuable for adaptation to climate change, there is now a need to put this understanding into practice. Building on the commitments to adaptation made by countries under the framework of the United Nations Framework Convention on Climate Change (UNFCCC) adaptation through ecosystem management must be integrated into policy-making, planning and practical initiatives on the ground. At the policy and planning level, it is important to identify actions related to ecosystem management in National Adaptation Programmes of Action (NAPAs) and National Communications (for non-least developed countries), particularly at the local level. There is an urgent need to integrate ecosystem management approaches into national commitments to address vulnerability and adaptation needs, including policy-making and planning at local and national, regional and international levels and to further strengthen these approaches within development policies and cross-sectoral planning. Part of this process will follow strengthened capacities to produce science that is relevant and can drive policy, as well as the creation of ecosystem assessments that can be more easily integrated into sectoral adaptation options.

At the global level, ecosystem-based adaptation has been widely recognized as an essential adaptation strategy. The Manado Declaration of May 2009 recognized that ' …healthy and productive coastal ecosystems, already increasingly stressed by land-based and sea-based sources of pollution, coastal development, and habitat destruction, have a growing role in mitigating the effects of climate change on coastal communities and economies in the near term' and recognized integrated coastal and ocean management as fundamental to preparing for and adapting to the effects of climate change on the ocean. Ministers and heads of delegations stressed the need to build conservation of marine ecosystems into national sustainability strategies to cultivate productive buffer zones that deliver valuable ecosystem goods and services that have significant potential for addressing the adverse effects of climate change. National and city-level policies should now reflect the commitments made at the World Ocean Conference of 2009.

Management frameworks, guidelines and protocols exist to counter this negative trend in ecosystem degradation. However, awareness, enforcement and investment are often lacking in order to reverse the trend. It is crucial that countries and cities become aware of their ecological values, invest in them and enforce management and protection policies. Ecosystem management and rehabilitation should be taken into account by urban planners in order to maximise the ecosystem services freely available to them, and in order to maximise the use of ecosystem services for adaptation to climate threats and creating resilient cities. Many management options are available to planners and managers in order to ensure maximum ecosystem-based adaptation benefits (see Table 43.1).

The United Nations Environment Programme (UNEP), United Nations Human Settlements Programme (UN-HABITAT) and ICLEI- Local Governments for Sustainability, jointly propose to assess, develop and implement ecosystem-based adaptation strategies for coastal cities in order to mitigate climate change effects and assist in the adaptation process. UNEP promotes ecosystem-based adaptation as a flagship strategy for adaptation to climate change because it is cost-effective, provides multiple benefits from various ecosystem services, builds on natural resources accessible to local communities as well as traditional knowledge and can complement other adaptation strategies, such as ecological resilience through biodiversity.

43.7 Some Possible Policy Recommendations for Urban Planners and Local Governments

1. It is recommended that local governments consider ecosystem-based adaptation options as an integral component of disaster risk reduction and climate change adaptation strategies, as part of local and national development planning processes.
2. Climate change related projects should take into account the local environmental conditions and habitats and identify opportunities for maximizing ecosystem services for climate change adaptation and disaster risk reduction. Locally appropriate species should be used and invasive species avoided as they can cause loss of biodiversity and habitat.
3. Local communities and stakeholders should be involved throughout the process to ensure well-designed, successful and sustainable ecosystem-based adaptation project and to avoid violating possible access rights.

Table 43.1 Coastal ecosystem-based adaptation options (Adapted from Hale et al. 2009)

Adaptation option	Climate stressor addressed	Additional management goals addressed	Benefits	Constraints
Allow coastal wetlands to migrate inland (e.g., through setbacks, density restrictions, land purchases)	Sea level rise	Preserve habitat for vulnerable species; preserve coastal land/development	Maintains species habitats; maintains protection for inland ecosystems	In highly developed areas, there is often no land available for wetlands to migrate, or it can be costly to landowners
Incorporate wetland protection into infrastructure planning (e.g., transportation planning, sewer utilities)	Sea level rise; changes in rainfall and precipitation patterns	Maintain water quality; preserve habitat for vulnerable species	Protects valuable and important infrastructure	
Preserve and restore the structural complexity and biodiversity of vegetation in tidal marshes, seagrass meadows, and mangroves	Increases in water temperatures; changes in precipitation	Maintain water quality; maintain shorelines; invasive species management	Vegetation protects against erosion, protects mainland shorelines from tidal energy, storm surge, and wave forces, filters pollutants, and absorbs atmospheric CO2	
Identify and protect ecologically significant ("critical") areas such as nursery grounds, spawning grounds, and areas of high species diversity	Altered timing of seasonal changes; Increases in air and water temperatures	Invasive species management; preserve habitat for vulnerable species	Protecting critical areas will promote biodiversity and ecosystem services (e.g., producing and adding nutrients to coastal systems, serving as refuges and nurseries for species)	May require federal or state protection

(continued)

Table 43.1 (continued)

Adaptation option	Climate stressor addressed	Additional management goals addressed	Benefits	Constraints
Integrated Coastal Zone Management (ICZM) – using an integrated approach to achieve sustainability	Changes in precipitation; sea level rise; increases in air and water temperatures; changes in storm intensity	Preserve habitat for vulnerable species; maintain/restore wetlands; maintain water availability; maintain water quality; maintain sediment transport; maintain shorelines	Considers all stakeholders in planning, balancing objectives; addresses all aspects of climate change	Stakeholders must be willing to compromise; requires much more effort in planning
Incorporate consideration of climate change impacts into planning for new infrastructure (e.g., homes, businesses)	Sea level rise; changes in precipitation; changes in storm intensity	Preserve habitat for vulnerable species; maintain/restore wetlands	Engineering could be modified to account for changes in precipitation or seasonal timing of flows; siting decisions could take into account sea level rise	Land owners will likely resist relocating away from prime coastal locations
Create marsh by planting the appropriate species – typically grasses, sedges, or rushes – in the existing substrate	Sea level rise	Maintain water quality; maintain/restore wetlands; preserve habitat for vulnerable species; invasive species management	Provides protective barrier; maintains and often increases habitat	Conditions must be right for marsh to survive (e.g., sunlight for grasses, calm water); can be affected by seasonal changes
Use natural breakwaters of oysters (or install other natural breakwaters) to dissipate wave action and protect shorelines	Increases in water temperatures; sea level rise; changes in precipitation; changes in storm intensity	Preserve coastal land/development; maintain water quality; invasive species management	Naturally protect shorelines and marshes and inhibit erosion inshore of the reef; will induce sediment deposition	May not be sustainable in the long-term, because breakwaters are not likely to provide reliable protection against erosion in major storms

Replace shoreline armoring with living shorelines – through beach nourishment, planting vegetation, etc.	Sea level rise; changes in storm intensity	Maintain/restore wetlands; preserve habitat for vulnerable species; preserve coastal land/development	Reduces negative effects of armoring (downdrift erosion); maintains beach habitat	Can be costly; requires more planning and materials than armoring
Remove shoreline hardening structures such as bulkheads, dikes, and other engineered structures to allow for shoreline migration	Sea level rise	Maintain sediment transport	Allows for shoreline migration	Costly for, and destructive to, shoreline property
Plant SAV (such as seagrasses) to stabilize sediment and reduce erosion	Changes in precipitation; sea level rise	Maintain/restore wetlands; preserve habitat for vulnerable species; preserve coastal land/development	Stabilizes sediment; does not require costly construction procedures	Seasonality – grasses diminish in winter months, when wave activity is often more severe because of storms; light availability is essential

4. All ecosystem services should be valued (when practical) and recognized when assessing the cost-effectiveness of different adaptation options.
5. Sustainable coastal development that reduces physical exposure to natural and man-made hazards exacerbated by climate change, should be promoted.
6. Adequate disaster preparation plans, including early warning systems, community awareness and evacuation plans, should be used in conjunction with ecosystem-based adaptation actions as part of disaster risk reduction and adaptation strategies.
7. Resilience of social and ecological systems to natural and man-made hazards as well as to the impacts of climate change should be enhanced through improved ecosystem management and sustainable resource use.
8. Ecosystem-based adaptation is not the only solution, but is a long-term cost-effective approach that can be used in conjunction with other disaster management and climate change adaptation measures in order to reduce the vulnerability of coastal populations.

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Chapter 44
Urban Agriculture and Climate Change Adaptation: Ensuring Food Security Through Adaptation

Marielle Dubbeling and Henk de Zeeuw

Abstract As cities expand, so do the food needs of urban families. The situation of the urban poor is precarious in the present context of volatile food prices and the financial, fuel and economic crises. The urban poor, often located in the most vulnerable parts of cities and lacking the capacity to adapt to climate-related impacts, will be hit hardest. The challenges associated with supporting the urban poor demand urgent and adequate responses from city and national authorities and international organisations. Urban policies need to incorporate food security considerations and focus more on building cities that are more resilient to crises. There is growing recognition of urban and peri-urban agriculture (UPA) as an important strategy for climate change adaptation and mitigation, to a lesser extent. Metropolitan, municipal and other local government institutions can play a proactive and coordinating role in enhancing urban food security and cities resilience by:

1. Integrating urban food security/UPA into climate change adaptation and disaster management strategies
2. Maintaining and managing agriculture projects as part of the urban and peri-urban green infrastructure
3. Identifying open urban spaces prone to floods and landslides and protecting or developing these as permanent UPA/multi-functional areas
4. Integrating UPA into comprehensive city water(shed) management plans
5. Including UPA in social housing and slum upgrading programmes
6. Developing a municipal urban agriculture and food security policy and programme.

Keywords Climate change adaptation • Food security • Urban agriculture

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44.1 The Impacts of Climate Change

The current challenge posed by climate change and its interaction with urban poverty and food security is recognised globally. As highlighted in one international conference organised by UN-HABITAT in 2009, 'Cities are a major part of the cause, suffering the most impacts and therefore play a primary role in finding the appropriate solution'. Climate change adds to the existing challenges faced by cities and their urban poor. Many cities are at risk of becoming disaster traps, due to the direct effects of sea level rise, floods or hurricanes or through severe food supply problems caused by droughts, hailstorms or frosts that affect agricultural production in their hinterlands. Indirect effects of climate change include the possibility of increased rural-urban migration.

The United Nations Population Fund (2007) indicates that the impacts of climate hazards disproportionately affect people 'who live in slum and squatter settlements on steep hillsides, in poorly drained areas, or in low-lying coastal zones.' Cities in these zones are at risk from flooding and extreme storm events. While low-elevation coastal zones represent 2% of the world's land mass, they hold 10% of its total population. There are 3,351 cities in such zones worldwide, 64% of which are located in developing regions, with many experiencing rapid expansion (UN-HABITAT 2009).

44.1.1 Food Supply Problems

Changing rainfall patterns will affect agricultural productivity, especially in African countries. Without the adoption of crop rotation and improved water conservation techniques, agricultural production could decline 10–25% by 2020 (Hans Herren, personal communication 2009). Lenton et al. (2008) state that southern Africa risks losing 30% of its coarse grain output by 2030 while Mozambique, Zimbabwe, and Malawi face as much as a 50% reduction in yields by 2020. In addition, the share of arable land in tropical regions is expected to decrease.

Climate change is expected to put 49 million additional people at risk of hunger by 2020, and 132 million by 2050 (IFAD n.d.). Urban economies will suffer as agricultural production in the surrounding countrysides is hit by storms, floods or water scarcity. The decline in agricultural productivity will thus not only effect the rural population but also the urban poor. Maxwell et al. (2008) state that 'urban and peri-urban areas are similarly impacted, as natural causes can lead to increased (temporarily or sustained) higher food prices, food shortages, epidemics, and sudden settlement of those displaced by the shock. To make matters worse, natural causes of food crises are often cyclical, repeatedly affecting the same regions or agro-climatic zones.'

While attention to adaptation in urban areas has been grossly inadequate to date, it has been suggested that the earlier that risk reduction and adaptation efforts are incorporated into city investment and development plans, the lower the unit costs will be (Reid and Sattertwhaite 2007).

44.1.2 Urban Heat Island Effect

A significant factor linking food security and climate change is the urban heat island effect. Buildings and surfaces, constructed of concrete and asphalt, heating, and transport systems, and, more importantly, the release at night of heat which has accumulated during the day in the fabric of the city (as the bricks and concrete of the buildings act as enormous storage heaters), in conjunction with the human and industrial activities of urban areas, have caused cities to have higher temperatures than their surrounding countrysides. The concrete and asphalt of cities increases run-off, which decreases the evaporation rate and further increases temperature. The annual mean air temperature in larger cities is often as much as 3–4°C higher than over open country, with a peak in the built-up core where on a calm, warm day the temperature difference may go up 11°C (American Meteorological Society 2000). The increased heat within cities causes discomfort and contributes to greater levels of energy consumption, used for cooling and refrigeration purposes, with a side effect of additional pollution.

44.1.3 Other Indirect Effects

As the effects of climate change may decrease productivity in marginal lands in rural areas, inhabitants will be forced to migrate to urban areas. Climate change could also contribute to current trends in the depletion of biomass energy resources. Reduced stream flows could lessen hydropower production, leading to negative effects on industrial productivity and more difficult and costly management of sanitation, waste disposal, water supply and public health in urban areas.

44.2 The Importance of Urban and Peri-urban Agriculture for Climate Change Adaptation, Sustainable Water Management and Building Resilient Cities

Urban and peri-urban agriculture and climate change adaptation: Urban and Peri-urban Agriculture (UPA) is increasingly recognized as an important strategy for climate change adaptation and mitigation, to a lesser extent. The World Meteorological Organization (WMO) has suggested that urban and indoor farming are necessary responses to ongoing climate change and as ways to build more resilient cities.[1] The Asian Cities Climate Change Resilience Network (ACCCRN), which brings together a number of international organisations in order to develop adequate strategies and action plans for city-level adaptation to climate change, has included urban and peri-urban agriculture as an important strategy to building resilient cities, or those able to respond to, resist and recover from changing climate conditions (Rumbaitis-del Rio 2009).

Urban agriculture, including agro-forestry, was also recognized at the International Tripartite Conference on urban challenges and poverty reduction in African, Caribbean and Pacific countries as having high potential for improving the urban environment and urban adaptation to climate change (UN-HABITAT 2009).

UPA helps cities to become more resilient by:

1. Reducing the vulnerability of most vulnerable urban groups and strengthening community-based adaptive management through:
   - Diversifying urban food sources, enhancing access of the urban poor to nutritious food, reducing dependency on imported foods and decreasing vulnerability to periods of low food supply from the rural areas during floods, droughts or other disasters;
   - Diversifying income opportunities of the urban poor and functioning as a safety net in times of economic crisis;
   - Being a source of innovation and learning about new strategies/technologies for high land and water efficient food production.
2. Maintaining green open spaces and enhancing vegetation cover in the city with important adaptive (and some mitigation) benefits including:
   - Reduced heat island effect by providing shade and enhanced evapo-transpiration (more cooling, less smog);
   - Reduced impacts related to high rainfall (by storing excess water), increased water interception and infiltration in green open spaces and keeping flood zones free from construction, reduction of rapid storm water runoff and less floods downstream and more replenishment of ground water;
   - Improved water quality through natural cleaning in low lying agricultural areas (e.g. natural or constructed wetlands, aquaculture in maturation ponds, etc.)
   - CO_2 and dust capture
   - Prevention of landslides by (agro-)forestry on steep slopes (and preventing building on such sites)
   - Conservation of biodiversity, protecting a wider base of plant (and animal) genetic diversity (Santandreu et al. 2002).

[1] "UN Agency calls for urban agriculture" WMO press release December 7, 2007.

3. Safely reusing wastewater and composted organic waste:
   - Adapting to drought by facilitating year-round production, safely using waste water flow and nutrients in water and organic waste;[2]
   - Reducing competition for fresh water between agriculture, domestic and industrial uses;
   - Lowering the depletion of certain minerals (e.g. phosphorus, by making productive use of the nutrients in wastewater and organic wastes[3]
   - Reducing landfill volumes and thus methane emission
4. Reducing their energy use and green house gas emissions by producing fresh food close to the city:
   - Using less energy in transport, cooling, storage, processing and packaging and enabling synergic and cyclical processes between urban domestic and industrial sectors and agriculture (e.g., use of excess heat, cooling water or CO_2 from industry in green houses);
   - Reducing the ecological footprint of the city via the energy and water needed to produce and transport the food consumed by it

However, urban agriculture, if not properly managed, may also have some negative impacts on the urban environment. Soil erosion and pollution of ground water may occur, if chemical fertilisers and pesticides are used over an extended period. Ecological farming practices are highly recommended in urban and peri-urban agriculture to prevent such negative effects.

44.3 The Way Forward: Building More Resilient and Food Secure Cities Through Urban and Peri-urban Agriculture

Urban and peri-urban agriculture can play an important role in responding to a range of challenges faced by developing countries when building more resilient cities. The size and urgency of these challenges require innovative solutions and

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[2] In water-scarce countries (especially in the Near East and North Africa, South Africa, Pakistan, and large parts of India and China) and in densely populated areas, growing competition between industrial, energy and domestic uses of water and agricultural use of water can be observed. When a country faces water scarcity, central and local governments tend to restrict agricultural water use in favour of urban industrial, energy and domestic uses, with important negative consequences for national food production (UN Water 2007). Meanwhile cities produce increasing quantities of wastewater that to a large extent is routinely disposed in rivers, lakes or the sea, with important negative effects on public health and the urban ecology, including the contamination of groundwater and pollution of fresh water bodies down streams of cities. Along with more efficient water use in agriculture, the productive use of treated urban wastewater and the use of rainwater have been identified as a sustainable way to produce food for the growing cities.

[3] Wastewater, excreta and urban organic waste are an accessible source of plant nutrients, such as phosphorus, nitrogen and potassium. The world's resources of readily available phosphorus are limited and will run out in 25 years (Rosemarin 2004). Nutrient recycling will reduce the need for artificial fertilisers and the energy needed for producing it.

the promotion of safe, sustainable and multi-functional urban and peri-urban agriculture is certainly key among them.

As cities are quickly becoming the principal spaces for planning and implementation of strategies that aim to mitigate or adapt to climate change, there is a growing need for metropolitan, municipal and other local government institutions directly concerned with urban development to play a proactive and coordinating role in enhancing urban food security and cities resilience by including urban agriculture in local climate change adaptation and disaster risk reduction strategies. In order to strengthen climate change adaptation in urban areas, city governments may take measures that include:

- Protecting and stimulating of sustainable urban and peri-urban agriculture in flood zones and wetlands and on steep slopes in order to prevent construction in such areas and to reduce run-off;
- Preferential food procurement from family- and community-based farms located within the city (e.g., government canteens, school feeding programmes) and facilitating direct marketing of fresh and ecologically produced food from regional sources;
- Involvement of urban poor producers in the maintenance of open green spaces such as greenbelts, green fingers, parks and other open spaces;
- Promotion of agro-forestry in order to reduce the urban heat islands effect and to enhance biodiversity and landscape management;
- Facilitating (safe) reuse of urban wastewater and organic waste in order to reduce waste disposal into open water systems, reducing fresh water use and recycling nutrients

In this context a shift to decentralised and low-cost treatment of wastewater, which would allow the reuse of wastewater and nutrients close to the source (stabilisation ponds, cluster approach, constructed wetlands) needs to be supported in tandem with decentralised collection and (co-)composting of organic waste and excreta. Health risks related to reuse of untreated waste water for production has to be reduced through complementary health risk reduction measures as explained in the new World Health Organisation (WHO) guidelines for safe use of excreta and wastewater (WHO 2006). Urban wastewater can be recycled and applied in a number of irrigation/fertilisation uses including floriculture and fruit crops irrigation, irrigation of forest plantations, combating desertification, providing fuel wood,[4] and turning steep slopes and low-lying lands into urban ‘green lungs’, that can also be used as recreational areas while creating flood buffers for neighbouring housing areas.

[4]In many cities attempts to decrease pressure on wood energy (fuel wood and charcoal) by subsidizing gas or electric technologies have not succeeded. The prognostic for many regions, such as in Africa, is that wood energy will continue to be the main source of energy for cooking and heating of the majority of their population.

44.3.1 Integration of UPA in Urban Development and Land Use Plans

Increased access of the urban poor to land and water, and especially enhanced security of agricultural land use, needs to be given proper attention. To this end, the integration of UPA into urban development and master plans, urban land use and zoning plans, as well as active maintenance of the protected agricultural zones against the land hunger of other urban interest groups is crucial. In most cities, there is no real shortage of land, but there is lack of pro-active management policies regarding use of land for food security and sustainable urbanisation. Since land is a valuable resource, combinations of different forms of land use (multi functional land use) for example by combining agricultural land use with recreational, water management/flood protection or other functions may be required.

In addition, various cities have taken innovative measures to enhance access of the urban poor to land including, for example:

- Integration of UPA in social housing and slum upgrading programmes by including space for home gardens or community gardens, street trees for shade and fruits, "productive parks", as in the Villa Viva and Drenurbes housing schemes in Belo Horizonte, Brazil;
- Making municipal land available to groups of urban poor households through medium-term lease arrangements or providing occupancy licenses to the urban poor producing informally on municipal land under the condition that they adopt safe and sustainable production practices (Governador Valadares, Brazil, and Cagayan d'Oro, Philippines). Municipal land that is provided might be land that is earmarked for other uses but not yet in use as such, such as land that is not fit for construction.[5] Such land is given on short- or medium-term lease arrangements to organised groups of urban poor for gardening purposes. Often these contracts with farmers include conditions regarding land, crop and waste management practices and include certain restrictions;
- Fiscal and tax incentives for land owners who lease out vacant private land to groups of urban poor willing to produce on this land (Rosario, Argentina)

44.3.2 Establishment of a Municipal Food Programme

Many cities have started municipal programmes to support the development of safe urban food production and consumption, often with a pro-poor focus. Besides enhancing and securing access to land and water and composted urban wastes, such programmes may focus on:

- Strengthening the organisation of urban producers and their capacity to design and implement projects to improve food marketing systems and participate in local

[5] These areas include flood zones, land under power lines, buffer zones and land reserves for future use.

planning activities (see FAO 2007). In Rosario, Argentina, the municipal urban agriculture programme supported the establishment of an Urban Producers Network and helped it link with other various governmental and non-governmental organisations. Peri-urban communities and agricultural cooperatives outside of Beijing are another example of innovative urban agricultural production and marketing projects.

- Providing training and technical assistance to urban producer groups and supporting them in implementation of their production and marketing activities and/or encouraging/enabling local non governmental organisations (NGOs), community-based organisations (CBOs), universities and colleges to do the same. Important topics for training are ecological farming practices, management of health risks, farm development, enterprise management and marketing.
- Support for infrastructure development and access to equipment and inputs.[6] The City of Cape Town for example transferred an old industrial site and building to an NGO supporting 3,000 urban producers. The site was converted into a packaging shed for green vegetables, a demonstration ground for ecological production technologies and a training centre.
- Enhancing access to efficient irrigation systems by delivering a minimum amount of fresh water free of charge to community gardens in slum areas (Cape Town, South Africa), by providing treated wastewater and training to poor producers operating in a peri-urban areas (Bulawayo, Zimbabwe), promoting systems for rainwater collection and storage (Mexico City), or constructing wells and establishing localised water-efficient irrigation systems (e.g. drip irrigation) in urban agriculture.
- Facilitating direct marketing of food products. Municipalities may facilitate marketing initiatives of poor urban and peri-urban farmers by providing them access to existing city markets, by assisting them in the creation of farmers' markets through infrastructure development, licenses, and quality control and by authorising food box schemes and green labelling for safe, ecologically grown urban food.
- Promotion of multi-functional land use. Under certain conditions urban farming can be combined with other compatible forms of land use. Farmers may provide recreational services to urban citizens, receive youth groups to provide ecological education, act as co-managers of parks, etc. In Calcutta, the maintenance of wetlands, agriculture and aquaculture are combined with waste water treatment and reuse. The Municipality of Beijing supports the development of peri-urban agro-tourism. Pretoria, South Africa, in partnership with producers, saves considerable maintenance costs by combining community gardening and recreational activities within municipal open green spaces.

[6] Assistance with infrastructure development may consist of storage spaces, packaging sheds, or green houses, while equipments and inputs may consist of irrigation equipment, quality seed, seedlings or young stock at cost or subsidised prices.

44.4 Final Remarks

The effects of recent crises in surrounding the global economy, food, energy, water and climate change are felt strongly by an increasing number of urban poor people. Adequate responses are urgently needed. Urban agriculture can play an important role in responding to these challenges, if it is incorporated into comprehensive approaches to sustainable urban development characterised by multi-stakeholder involvement, decentralised and flexible approaches, participatory planning and management of spaces and services, pro-poor focus and optimal use of locally available resources (including wastes).

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Chapter 45
Cooling the Public Realm: Climate-Resilient Urban Design

Jeffrey Raven

Abstract As communities strive to meet the challenges of changing global conditions, urbanists are called upon to shape built environments that can adapt and thrive in the changing global conditions, can meet carbon-reduction goals, and can sustain urban populations in more compact settings by providing amenities that people need and want. This paper explores urban design strategies to strengthen urban resilience through a systemic, interconnected public realm to achieve reduced energy loads, cleaner air and enhanced civic life.

Keywords Architecture • Planning • Resilient • Sustainability • Urban design

45.1 Introduction

Global climate change has rendered traditional urban design processes obsolete. A new paradigm is required in order to develop resilient cities able to adapt and thrive in changing global conditions, meet the requirements of carbon-reduction and other environmental measures, and sustain compact urban populations by providing necessary and desirable amenities for urban residents. The scope and speed of current changes demand that urbanists define compelling visions and integrated design measures for shaping resilient cities. From energy and transportation to water and green infrastructure, urbanists can shape these systems to shrink our ecological footprint, configure resilient urban form and adapt our cities to climate change (Figs. 45.1 and 45.2).

As global temperatures rise, a central challenge will be to create compact, cool urban settlements. This requires informed knowledge of climate-resilient urban design, drawing from fields such as urban climatology and sustainable

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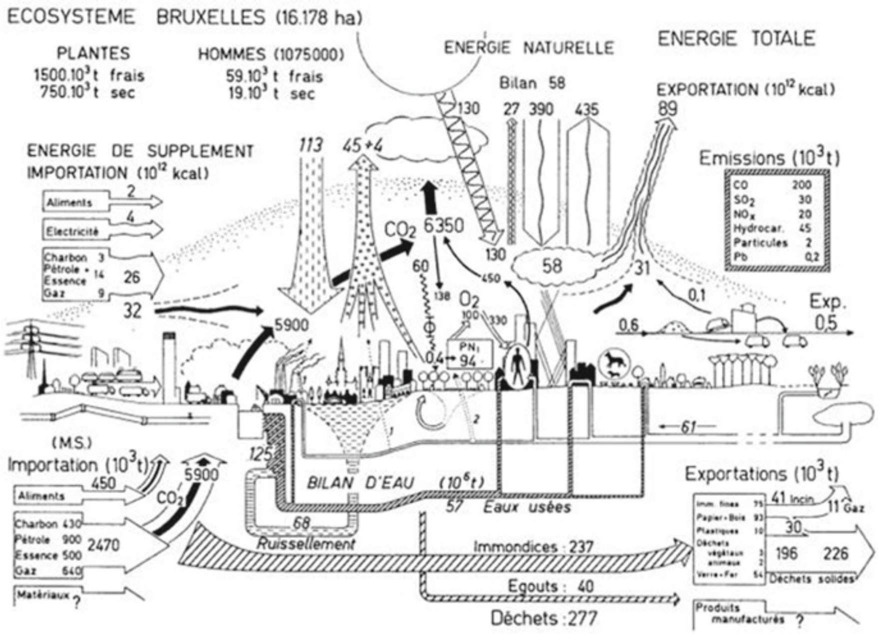

Fig. 45.1 Inputs and outputs: a systemic approach to an urban context across sectors and scales (Source: Duvigneaud and Denayer-de-Smet 1975)

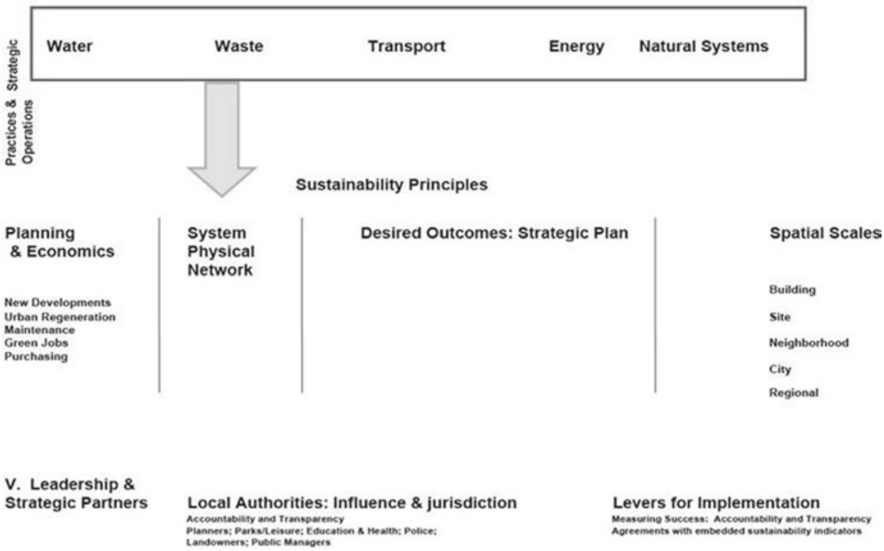

Fig. 45.2 An integrated sustainable planning process (Adapted from CABE 2009 http://www.sustainablecities.org.uk)

design. However, despite considerable technical knowledge within these fields, climate-resilient urban design has not yet emerged as a major consideration in standard urban design practice.

45.2 Sustainability Rating Systems

Sustainable Designation Systems, or sustainability rating systems, are currently in development in the United States at the neighbourhood and district scales, with the aim of developing sustainable communities throughout the country. This paper suggests morphological and climate-resilient urban design measures for the rating systems. The term morphological here describes the simplified three-dimensional form of the built environment and the spaces it creates. These climate-resilient urban design measures should be adapted to sustainability rating systems with pilot testing evaluation criteria for measuring benefits.

The prototype sustainability rating systems STAR Community Index (STAR), US Green Building Council's (USGBC) LEED for Neighbourhood Development (LEED ND), and the international Clinton Climate Initiative's Climate Positive Development Program (Climate+) provide opportunities for developing climate-resilient urban design prescriptive measures and performance standards for broad implementation.

Municipal governments are the targets of the STAR Community Index, with sustainability broadly defined to include equity, economy and environment. Its policy-driven mandate ranges from urban design to local economy to social justice (ICLEI 2009a). The primary target audience of LEED ND is the building industry, including property developers and architects. Its project-driven mandate ranges from storm water capture to traffic-calming and urban density incentives (USGBC 2009). The primary targets of the Climate Positive Development program are public-private partnerships required for large international developments. Its project-driven mandate hinges on reducing the amount of on-site CO2 emissions to below zero (Clinton Climate Initiative 2009). These rating systems all aspire to become gold standards for their target audience and provide robust metrics with which to measure success. They are currently in various phases of development, and it remains to be seen if the final versions of these systems will overcome considerable challenges to address climate-resilient urban design strategies for climate adaptation and test pilot projects for future resiliency.

Given its ambitious scope, varied scales and geographic diversity, the STAR Community Index may be the most challenging of the sustainability rating systems with which to measure success. The *Measuring sustainability briefing* (ICLEI 2009b) describes how USGBC's LEED rating systems provide a precedent for measuring progress and how indicators of performance can play a role in the STAR Community Index. The STAR Community Index is a sustainability framework conceptualized as a designation type of rating system which relies on prescriptive measures and performance standards to set achievement levels of the attainment of points or credits within the system (ICLEI 2009b).

Table 45.1 Broadening traditional place making urban design qualities with sustainability supporting qualities (Odeleye 2008)

Traditional urban design "choice-supporting" paradigm compared to "sustainable" urban design	
Traditional urban design	Sustainable urban design
Permeability – connectivity	Resilience – adaptive
Vitality – interactions	Comfort – environment permeability
Variety – options	Resource efficiency – demand, synergy, re-use
Legibility – understandable	Biotic support – environmental diversity
	Health – pathological prevention

A climate-resilient urban design strategy requires expanding traditional place-making urban design qualities to include principles of sustainable design such as resilience, comfort, resource efficiency, and biotic support (see Table 45.1). Applying these principles to sustainability rating systems helps to identify and strengthen prescriptive measures and performance standards. These will address threats posed by climate change on the public realm – by focusing on public realm vulnerabilities and adaptive opportunities through climate-resilient goals, measures and performance indicators. An additional challenge will be to create the tools necessary to assess conditions of urban environments at city block or neighborhood scale. In present practice there is a lack of clarity concerning the impact of regional decisions on neighbourhood or individual scales and vice versa. The need for transparent planning processes between local and regional scales and clear accountability are two additional aspects that should be considered in the context of efficient rating systems.

45.3 Principles of Climate Resilient Design

Climate-resilient public realm measures would strengthen community adaptability to climate change and mitigate the urban heat island effect through the creation of systemic, interconnected and protective micro-climates within the public realm intended to reduce energy loads, produce cleaner air and enhance civic life. Prescriptive measures and performance standards for a climate-resilient public realm would address systemic impacts on the public realm, including urban ventilation, green infrastructure, and solar design. Urban surface reflectivity (albedo), sky visibility (sky-view factor) and anthropogenic (user) emissions remain key elements within these categories.

45.3.1 Ventilation and Green Infrastructure

Urban ventilation and green infrastructure strategies capitalize on prevailing breezes to improve air quality while mitigating the urban heat island effect.

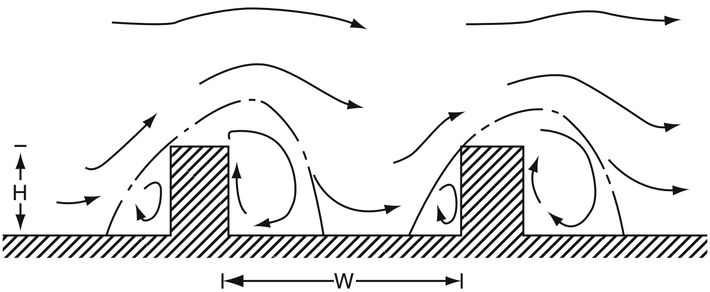

Fig. 45.3 Wind flow associated with different urban geometry and surface roughness (Oke 1988)

Fig. 45.4 City model detail: green fingers through dense, energy-efficient, pedestrian-friendly neighborhoods of cool streets, urban squares lower building cooling loads, Masdar carbon-neutral development, Abu Dhabi (Source: Fosters + Partners 2009)

Wind affects temperature, rates of evaporative cooling and plant transpiration and is thus an important factor in implementing district-wide passive cooling strategies at a micro-climatic level. Urban morphology is responsible for varying the surface roughness (see Fig. 45.3) and porosity of the city that impacts airflows effectiveness in passive cooling and reducing energy loads in the built environment.

Summer breezes across parks, green roofs and water bodies can accentuate the cooling effect, and alignment of street canyons can be used for external cooling but also can be effective for passive cooling in buildings. For example, Masdar's streets are mainly used for pedestrian circulation, fresh air distribution, and microclimate protection. Its two green park bands that stretch throughout the city are oriented toward the sea breeze and the cool night winds (see Fig. 45.4).

Fig. 45.5 Green and blue fingers: contiguous green corridors and canal circulation networks; punctuated by storm water retention bodies as urban design amenities; Thanh Hoa City by 2020 (Source: Raven-LBG 2008)

Fig. 45.6 Urban design treatment of green corridors and canal circulation networks as urban gateway elements, Thanh Hoa City by 2020 (Raven-LBG 2008)

The *Thanh Hoa City by 2020* plan in northern Vietnam uses similar strategies in a tropical climate, where linear parks along canals align with prevailing summer winds to create fresh air corridors through the city grid (see Fig. 45.5). The viability of these passive ventilation strategies hinges on considerations across other urban sectors, from transportation to anthropogenic heat sources from day-to-day activities of city inhabitants (see Fig. 45.6). In Masdar, streets continue serving city-wide circulation, but phasing out internal combustion engines from city streets in favour of electric vehicles removes important air quality and noise challenges (Schuler 2009).

45.3.2 Solar Design and Thermal Comfort

Solar design is an effective passive strategy to increase comfort and reduce energy loads at a neighbourhood scale. The urban canyon, which is a simplified rectangular vertical profile of infinite length, has been widely adopted in urban climatology as the basic structural unit for describing a typical urban open space (Ali-Toudert et al. 2005). For street canyon geometry, one of the most useful measures of the urban terrain is the Sky View Factor (SVF) (see Fig. 45.7) which expresses the relationship between a surface and sky, and introduces the concept of opening or closing the space.

In addition to vertical profile, the orientation of the urban canyon has a decisive impact on the human thermal sensation at street level. Patterns of urban settlement based on climate, topography and geology highlight the important relationship between passive climate-resilient strategies derived from urban form and a comfortable public realm. For example, the diagonal grid with 45° diagonal orientation off cardinal points leaves every street with some direct sunlight during winter months,

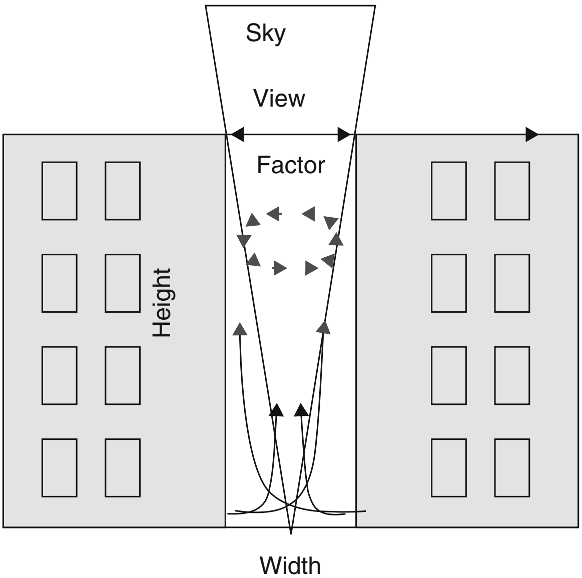

Fig. 45.7 Cross-section through a symmetrical urban canyon. Height is the building height and urban canopy height. Width is the separation between buildings. Sky View Factor is defined as the proportion of the viewing hemisphere occupied by the sky. *Red arrows* illustrate heat trapped within urban canyon or reflected to the sky, depending on urban geometry and surface materials

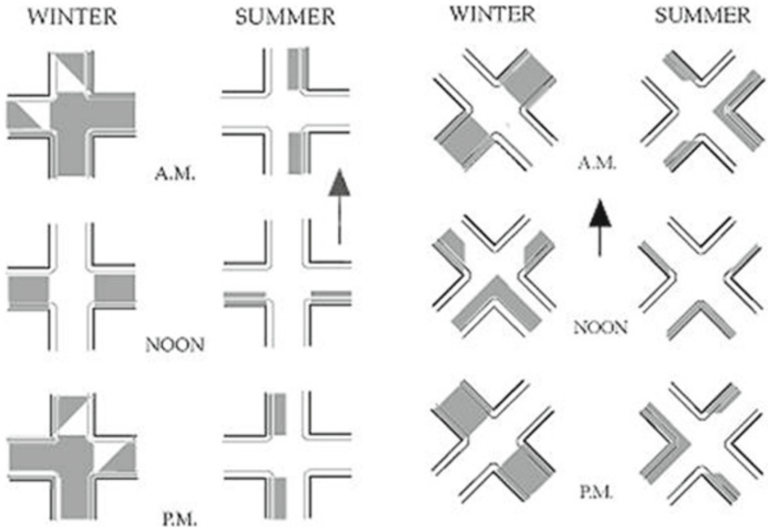

Fig. 45.8 Jeffersonian grid (*left*) runs along north-south cardinal points; Spanish grid (*right*) with 45° diagonal orientation off cardinal points (Source: Walter et al. 1992)

and some shadow during most of the summer day, although it is important to balance preferred street configuration against optimal building configuration (see Fig. 45.8).

There is currently no single "silver bullet" climate-resilient urban design tool that has been developed across spatial scales and sectors. Researchers have determined that more than a single tool will be necessary. This iterative, spatial, scalable, synthetic, multi-issue, accessible, and economical set of tools would share a common engine of methodological concepts and standards (Miller et al. 2008).

At a regional scale, the quantity of radiant heat energy emitted by low-density, largely single-family districts can be determined with the aid of remotely sensed thermal data collected by the National Aeronautical and Space Administration (NASA). Comparing low-density with higher density 'compact' districts in Atlanta, this research has argued for a nuanced analysis of the relationship between land use density, urban morphology and the urban heat island effect. The research argues that thermal efficiency (based on thermal emissions) per single-family plot of land actually increased in higher-density compact districts (see Fig. 45.9). This finding directly challenges common assumptions that higher residential densities are less thermally efficient than lower residential densities.

In a Martin Centre study at the University of Cambridge, archetypal generic built forms from an urban block arrangement derived from a simplified urban fabric were linked to solar exposure (Ratti 2003). These archetypal, generic urban form patterns could be characterized to form the basis for applying morphological indicators (see Fig. 45.10).

Those, in turn would be the basis for prescriptive measures and performance standards. For example, it is possible to characterize a limited number of generic North American neighbourhood configurations and the related district configurations

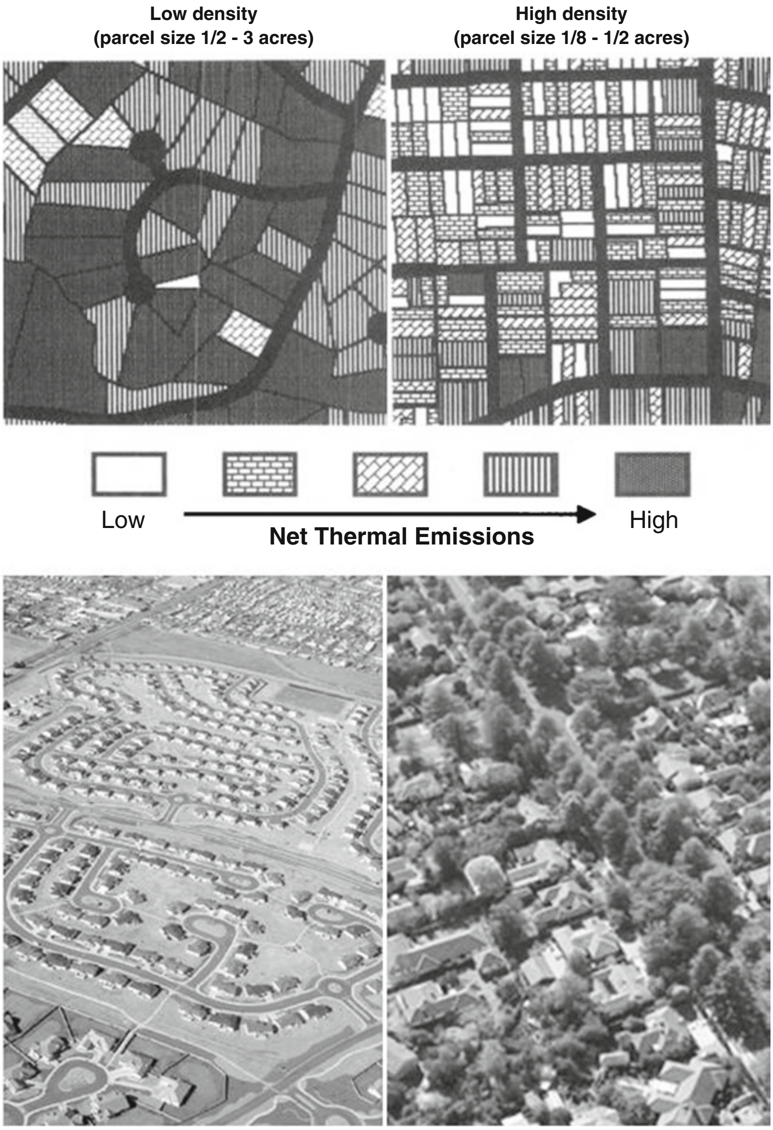

Fig. 45.9 (*Top*) Urban form related to thermal efficiency. How the design of cities influences the urban heat island effect (Stone et al. 2001). (*Lower left*) New suburban sprawl: low-density development, low-efficiency thermal emissions per parcel (Source: http://www.re-nest.com/uimages/re-nest/5-11-2009suburb.jpg). (*Lower right*) Higher density residential development, mature tree canopy layer, higher-efficiency thermal emissions per parcel (Source: http://www.davidwallphoto.com)

into which they assemble. Once characterized, the inherent or potential climate impacts from this small palette of neighbourhood types and limited set of inputs could be assessed, thereby avoiding the necessity of assigning attributes on a much

Fig. 45.10 An elementary framework composed of basic urban form patterns and morphological indicators (Source: Ratti 2003)

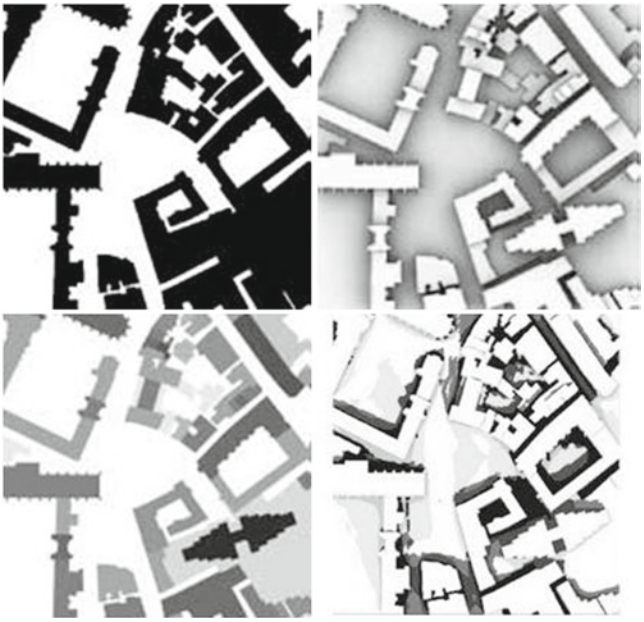

Fig. 45.11 Illustrating selections from suite of tools, determining comfort or "desirability" factor in the public realm, based upon individual microclimatic variables (2004). Clockwise: Figure-ground map; Sky-view factor (SVF) map; Open space diversity profile; Digital elevation model (DEM) (Source: Steemers, et al. 2004)

smaller parcel by parcel scale. Once assembled, these patterns could then be used to generate regional scenarios. With this method, it would be possible to develop a tool that would simplify data input, analyse scenarios quickly and cheaply, and potentially function in real-time in collaborative, public processes (Miller et al. 2008).

If height information is included at a more detailed level, a Digital Elevation Model (DEM) could be developed, which is an image where each pixel of the figure-ground map has a grey-level proportional to the urban surface (see Fig. 45.11) (Ratti et al. 2003).

By correlating urban form and various aspects of environmental performance with respect to the solar and wind environments and energy consumption, an evaluation of the environmental impact of alternative urban forms can be accomplished without the need for elaborate models.

Sky view factor (SVF), the proportion of sky visible in a 180° field of view, or the aspect ratio, the height of the street canyon divided by its width, are both readily quantifiable measures of urban terrain (Smith et al. 2008). By applying image processing techniques to three-dimensional urban textures, a suite of tools can draw connections at a simplified level between urban form and microclimate characteristics (Steemers et al. 2004). More sophisticated software is increasingly available for simulating sunshine, lighting and thermal radiation to determine micro-climate impacts of three-dimensional urban form. These tools evaluate sunshine/shadow; solar energy, solar reflections, luminous transmission and thermal radiation as factors that shape the comfort profile of the public realm.

45.4 Conclusion

The Pilot Test methodology for the rating systems should measure the success of these climate-resilient urban design strategies across different spatial scales, geographies and climate. The development of rating systems, such as STAR, LEED ND, and the Climate Positive Development Program should involve a sequence of phases, each with feedback loops to test the systems logic and validity. As these rating systems become fully operational, it will be possible to model and test the micro-climate indicators of an actual climate-resilient urban design pilot goal. This paper suggests a prototype framework and methodology for the Pilot Phase so as to evaluate the future results.

The quantitative climate-resilient assessment of a rating system pilot case-study would include the use of two sets of archetypal standard urban patterns for study, targeted to a varied group of city types, climates and geographies. This could range from a high-density urban core to an inner-ring suburb to an edge city, from subtropical to desert. One set for each location would be a "baseline" conventional urban design pattern. The second set would represent "best practice" urban form suitable to local conditions. Built in the same locations as the archetypal models, actual sustainable rating system-accredited Pilot Community projects would be evaluated in real time against these two sets of benchmarks.

The three sets, baseline model, best practices model and actual Pilot Community project would be tested based on climate-resilient urban design indicators discussed earlier in this work. The suite of tools would evaluate albedo, sky view factor, solar design and urban ventilation. Anthropogenic heat sources from city inhabitants should also be factored in. For lower-density, uniform morphologies, radiant heat energy could be modelled to simulate the thermal efficiency study of residential districts described earlier. For more localized urban spaces, the three-dimensional micro-climate analysis would begin to suggest unique diversity and desirability profiles.

To account for climate change, these indicators should assume at least two plausible future climate conditions: increasing temperature (20 and 90 years time period) and increasing intensity of heat wave events, based on weather data (Pyke et al. 2007). A modest change scenario would be equivalent to extrapolating the observed trend for 20 years (a typical time horizon for planning). A longer-term change scenario would be equivalent to extrapolating the observed trend 90 years into the future (i.e., end of the twenty-first century, a benchmark often used in climate change analyses). These changes should be applied to a ten-year historical daily climate record (1996–2005) from each of the nine representative cities (Pyke et al. 2007). For the United States, nine Pilot Communities could be selected based on geographic variation, representing each of nine US National Climate Data Center (NCDC) regions.

The climate adaptive performance of the Pilot Communities should compare morphological urban design indicators against conventional baseline condition and best practice models. The important question in evaluating the results would be: do the pilot tests accurately predict performance? It would be important to create effective feedback loops so that this information continues to shape the rating systems.

A prototype testing protocol similar to the one suggested here could provide transparency and accountability to the decision-making process. As these rating systems continue through the prototype phases, developing transparent testing protocols backed by clear accountability will be the next stage of the work. Climate mandates from federal, state and provincial governments are now impacting the practice of urban design as cities face mandates to bring their transportation, zoning, building codes and economic development policies into alignment with required greenhouse gas reduction goals and reduce vulnerabilities from that part of climate change that is already unavoidable. This development has signalled a shift in focus in urban design policies from greenhouse gas emission mitigation strategies to risk analysis, adaptation and resilience.

The half-century design life for the built environment means that current urbanists and policymakers must create resilient cities within paradigms appropriate for future climates. Under changing conditions, solutions requiring fewer resources, rather than more, are likely to be robust, which is why reducing energy demand through climate-resilient strategies is such an important first step. This approach can reap significant benefits in the long term, including economic savings and risk reduction through reduced energy consumption, while improving the ability of communities to thrive despite heavy impacts related to climate change.

Forward-thinking cities should exploit climate-resilient urban design measures in order to future-proof their built environments in expectation of continuing climate change. Passive urban design strategies to lock in long-term resilience and sustainability should be promoted; this would reduce reliance on applied technologies that may require expensive maintenance or quickly become obsolete.

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Chapter 46
The Role of Transport in Mitigation and Adaptation to Climate Change Impacts in Urban Areas

Giuseppe Inturri and Matteo Ignaccolo

Abstract This paper is part of the Green and Blue Space Adaptation for Urban Areas and Eco-towns (GRaBS) project, funded by the EU with the objective of improving the adaptive capacity of towns and cities to the impacts of climate change. The aim of this contribution is to facilitate the inclusion of climate variables into the decision-making processes within the planning, design and operation of the transport system. The aim is to accomplish this through pursuing win-win solutions which both mitigate the future effects of climate change at the global scale, while strengthening the local adaptive capacity of transport systems to cope with the inevitable impacts of changes in climate. The paper further shares the main objective of the GRaBS project, to promote climate-resilient urban development through green and blue infrastructure, largely through enhancing walking and cycling as the most climate-sustainable modes of transport.

Keywords Adaptation • Climate change • Green infrastructure • Mitigation • Transport

46.1 Impact of Transport on Climate Change

46.1.1 Scale and Nature of the Problem

The proportions of greenhouse gas (GHG) emissions from transport sources are estimated at 13% worldwide (IPCC 2007), 27% in the USA (US EPA 2007), 24% in Europe (EEA 2009), 30% in the UK (CFT 2007), and more than a quarter (27.9%) of total CO_2 (carbon dioxide) emissions in the EU27 in 2006.

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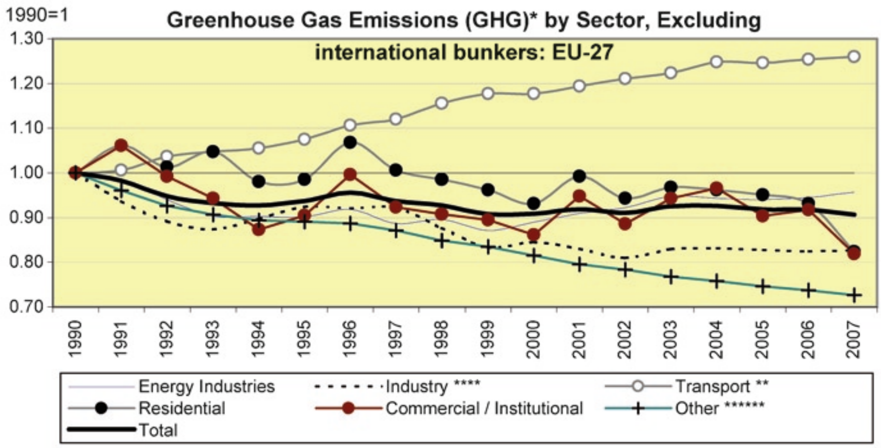

Fig. 46.1 GHG emissions by sector, EU27 (Source: EEA 2008)

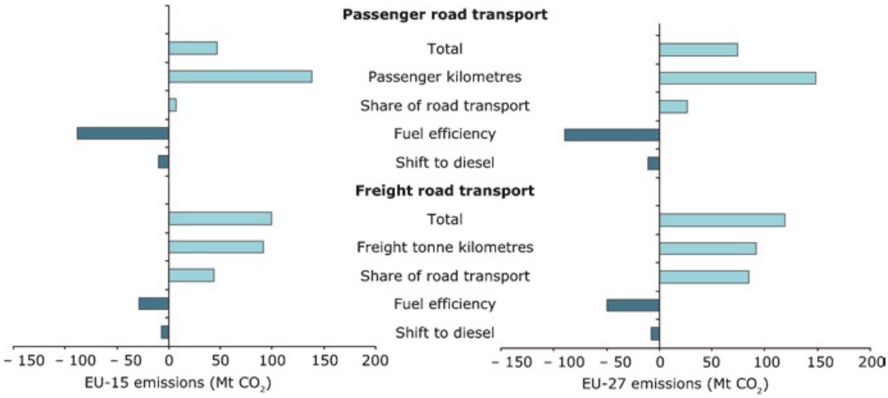

Fig. 46.2 Main drivers of CO_2 emission trends from road transport (passenger and freight) in the EU27 and EU15, 1990–2007 (Source: EEA 2009)

Road transport accounts for more than 72% of all transport-related CO_2 emissions in Europe (EC 2008). The number of cars per 1,000 persons has increased from 232 in 1975 to 460 in 2002. The overall distance travelled by road vehicles has tripled in the last 30 years. Therefore, while the emission rates of most GHG sources are starting to ease off, transport-related emission rates are still steadily increasing (up by 29% on 1990 levels in the EU27 countries in 2006 – see Fig. 46.1) and are expected to continue growing faster owing to rising transport demand, in terms of both passenger kilometres and tonne kilometres (see Fig. 46.2).

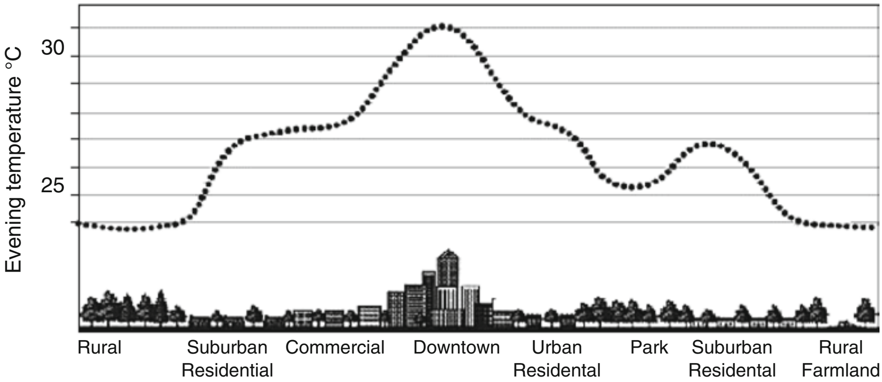

Fig. 46.3 Urban heat island effect (Source: http://heatisland.lbl.gov/HighTemps/)

The impacts of global warming caused by GHG emissions are amplified in urban settings, because of the urban heat island effect, or urban areas with higher temperatures compared with their suburban and rural surroundings (see Fig. 46.3). This phenomena is caused by the absorbing dark materials of buildings and pavements, with serious implications for urban dwellers. In 2003, for example, a summer heat wave killed 52,000 people across Europe (Robine et al. 2008).[1]

46.1.2 Mitigation Strategies

Basic measures to mitigate the transport-related contribution to global warming is to curb GHG emissions through:

- improved vehicle efficiency, to produce less emissions;
- cleaner fuels, to reduce GHG emissions per kilometre travelled; and
- reductions in driving, reducing both the distances travelled per trip and the number of trips.

While remarkable efforts have been made during the last decade to reduce carbon emissions by developing cleaner fuels and improving vehicle efficiency (see Fig. 46.4), driving continues to increase. In the period 1995–2006 Europe has experienced a road transport related GHG emission growth rate of 1.53% (EC 2010) against an annual rate of population growth of 0.28% (see Fig. 46.5).

[1]Though it is not determined whether additional deaths occurred in urban settings, it is highly probable, as more than 80% of European population lives in urban areas and because the urban heat island effect is likely to exacerbate the impacts of heatwaves. For additional information, please see the Comptes Rendus Biolgies report (referenced).

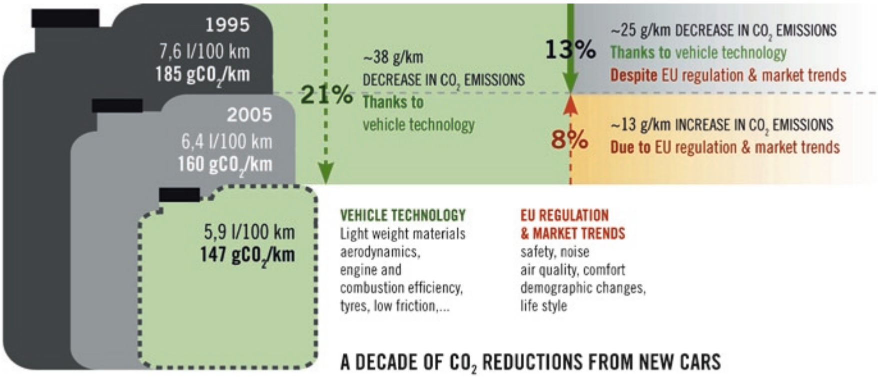

Fig. 46.4 Improvements in vehicle technology (Source: ACEA 2008)

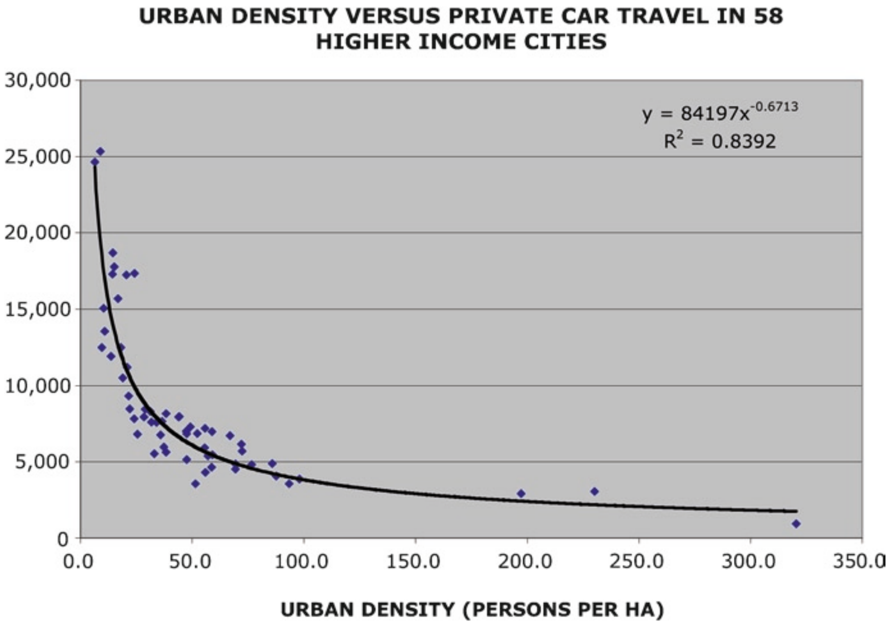

Fig. 46.5 Annual car use per capita and urban population density (Source: Kenworthy et al. 1999)

A great number of studies also recommend new approaches to urban planning as solutions to delivering meaningful reductions in GHG emissions. Examples include Smart Growth (ICMA 2002) and Transit Oriented Development (Calthorpe 1993; La Greca et al. 2009), both of which advocate for development of high mixed-use densities in areas close to public transport nodes and within 'walkable' communities. These development strategies are arguably the most effective strategies for reducing short distance car trips and improving transit efficiency.

On the other hand, adapting to climate change requires that space be given over for green and blue infrastructure within and around built areas, because densities that are too high can exacerbate the urban heat island effect and increase the likelihood of urban flooding. This conflict is an example of how mitigation actions could compromise adaptation objectives. It suggests that climate change must be tackled by integrating mitigation measures, such as limiting the production of GHG emissions, with adaptation measures in order to prepare our cities for the inevitable impacts of climate change.

46.2 Impacts of Climate Change on Travel Behaviour

Research has suggested that even if GHG emissions were to immediately halt, we would still feel residual impacts of climate change for decades to come. With regard to travel behaviour, increases in temperatures may extend summer travel patterns, while changes in precipitation may influence how attractive walking or cycling will be to pedestrians and cyclists. While these behaviors may be considered as minor adaptation responses, the cumulative impact of mobility in urban areas will make these changes very important. This is quite an unexplored area of research, and deeper investigation is needed. A comprehensive overview of empirical findings on the subject can be found in the work of Koetse and Rietveld (2009), while a short synthesis of recent research is provided in the following paragraph.

Fridstrom (1999) estimates the seasonal effects of monthly mean temperature on road use demand with an elasticity of 0.068.[2] A study by Chung et al. (2005) on the Tokyo metropolitan expressway finds that travel demand on weekdays decreases by 2–4% as rainfall increases from 1 to 30 mm per day, while larger reductions occur over the weekends (from 4% to 14%). Richardson (2000) shows that cyclists are less likely to ride in very cold or very hot weather (see Fig. 46.6), while increasing daily rainfall also reduces the propensity to cycle, with leisure trips more likely to be influenced than commuting trips.

An econometric analysis by Aaheim and Hauge (2005) shows that increased rain makes walking and cycling less attractive As travel distance shortens (except for travel to work), it may have a stronger effect on favouring walking and cycling. Sabir et al. (2008), using a multinomial logit mode choice model, find that people use cars and public transport more in low temperatures; accordingly they switch from car to bicycle as temperature increases. However, if temperatures reach levels higher than 25°C, people switch back from bicycle to car and

[2] Price elasticity of demand is a measure used in economics to show the responsiveness, or elasticity, of the percentage change in quantity demanded of a good or service in response to a 1% change in price. Being the ratio between 2%, elasticity is a pure number, therefore without measurement unit. The same concept is also used with variables different from price. In this context an elasticity of 0.068 of road use demand means that an increase of 10% of the monthly mean temperature determines an increase of 0.68% of travelled vehicle-kilometers.

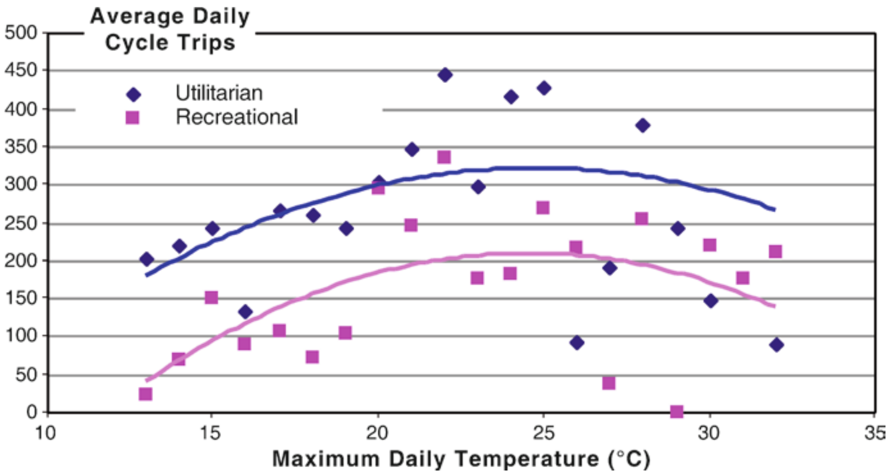

Fig. 46.6 The effect of temperature variations on cycle flows (Source: Richardson 2000)

public transport. An increase in the duration of sunlight produces a small shift from car/public transport to cycling/walking. Strong winds also affect the likelihood of using the bicycle, but not other modes of transport.

46.3 Planning for Adaptation

Adaptation planning has begun to feature within the climate action agenda (EC 2009b), especially at local levels, where the benefits of reducing communities' vulnerability to the dangers of climate change will be more evident. Adaptation options can be classified into three broad categories (EC 2009a):

- A grey infrastructure approach, focusing on engineering techniques and infrastructures, aimed at providing physical protection against climate impacts such as floods and sea level rise, and preventing the adverse effects of climate variability, through heat-resilient road pavements, air conditioning, etc.
- A green infrastructure approach, based on strengthening the resilience of ecosystems, using trees and green spaces to enhance cooling capacity and lessen flood impacts.
- A soft approach, based on the application of policies, procedures, information, communication, education, economic incentives and other price signals.

46.3.1 GRaBS Approach

The GRaBS project mainly focuses on green infrastructure and soft approaches, seeking to raise awareness on how green and blue infrastructure, including parks, gardens, green corridors, green roofs and water bodies, rivers, streams and sustainable

Fig. 46.7 Drainage system, Augustenborg, Malmö, Sweden

drainage systems (see Fig. 46.7), can play a vital role in creating climate-resilient development – a role which is currently not sufficiently recognised nor integrated into mainstream planning.

The project is largely based on the modelling work of Handley et al. (2007a, b), Handley (2009) which found that the use of urban green space offers significant potential in moderating predicted increases in summer temperatures. However, in many existing urban areas where the built form is already established, green space will have to be added via, the greening of roofs, building façades and railway lines, tree planting, and conversion of selected streets into greenways.

46.3.2 Urban Mobility and Green Infrastructure

This leads to the concept of the green infrastructure network – a set of connected green elements, ranging from public and commercial building green spaces to district parks and river banks, parkways and street tree canopies, greenways (footpaths and cycle routes), doorstep communal green spaces adjacent to dwellings, and private gardens. Such networks should link residential areas to public open spaces and natural green corridors (Urban Task Force 1999) using a bioclimatic approach to urban design aimed at providing effective climate resilience and greater human comfort.

Additional research is required to identify the pattern of green infrastructure best able to deliver air conditioning, microclimate control and flood attenuation.

As discussed by Scudo (2005), while the contribution of large green structures (urban forests, green belt, large parks etc.) to urban microclimate mitigation is quite well known (Oke 1988), the mitigation capability of small green urban structures is less known.

To avoid reductions in urban density resulting from the creation of large green spaces, it may be better to adopt linear parks and greenways adequate for cycling and walking. An interesting case study of this approach has been provided by the residential area of Oakwood, within the Birchwood district of Warrington New Town (Tregay and Gustavsson 1983). Though the implementation of designed ecosystems has been successful in Warrington New Town, the function of greenways as pedestrian routes have been less so. The layout resulted in small estates becoming isolated, without proper signage and lighting. Several decades ago, Jacobs (1961) warned that if a park was not located near a sufficient mix of land uses – economic, cultural, residential, commercial – to ensure its use at all times, this might result in an empty and degraded urban space, with negative impacts on sustainable mobility.

It may therefore be wise to focus on combining medium-density housing with a network of medium size green spaces in a variety of forms – such as parks and paved spaces with some green, large wooded areas and small patches of grass; rows of overarching trees lining the streets; green façades; lawns and green roofs – and connected by shorter and appealing non-motorised paths connecting to major urban areas and activities.

46.3.3 Green Spaces and Walking

Walking and cycling are the most sustainable modes of transport, and an increased adoption of these modes will make major contributions to mitigation. Research efforts are needed to better understand how green spaces may better encourage non-motorised mobility. The work of Martincigh (2002, 2005) is significant to this area, as it explores the function of green infrastructure in promoting sustainable mobility and provides the following guidelines:

- The green network must be dense, and easily accessed by every pedestrian walking towards various attraction poles;
- The green links must provide direct routes, in some cases passing through private green spaces and inner courtyards;
- In relation to vehicular traffic, green links must allow priority to pedestrians at points of intersection;
- These links must guarantee comfort, including thermal, visual, acoustic, olfactory, tactile, respiratory, hygienic etc. to pedestrians, provide shading and ventilation in summer and shelter against wind and rain in winter;
- Links must communicate security through well-designed lighting

46.3.4 Street Trees

Recent studies, such as the NYC Regional Heat Island Initiative (2006) have shown that street trees have the greatest per-unit-area potential for cooling and the greatest potential to alter the albedo[3] of urban surfaces compared with other vegetation (see Fig. 46.8). Streets thus integrate different synergic roles including traffic infrastructure, appropriate spaces for hosting walking and related social and recreational activities and regulators of microclimatic conditions within green networks.

The concept of multi-way boulevards (see Fig. 46.9) is significant in this context, as they move an amount of traffic equivalent to that of comparable arterial streets, while allowing easy access, pedestrian activities for commercial and residential users via distinctive features of tree-lined pedestrian paths (Jacobs et al. 2002).

Toudert (2005) also contributes to the debate surrounding the development of comfortable street-level microclimates for pedestrians, dealing with the influence of geometry and street irradiation patterns as well as the effects of heat on the human body. Toudert further provides a quantitative evaluation of the thermal effectiveness

Fig. 46.8 Street trees

[3]The albedo of an object is a measure of how strongly it reflects light from light sources such as the sun. Albedo is defined as the ratio of total-reflected to incident electromagnetic radiation. It is a unitless measure indicative of a surface's or body's diffuse reflectivity.

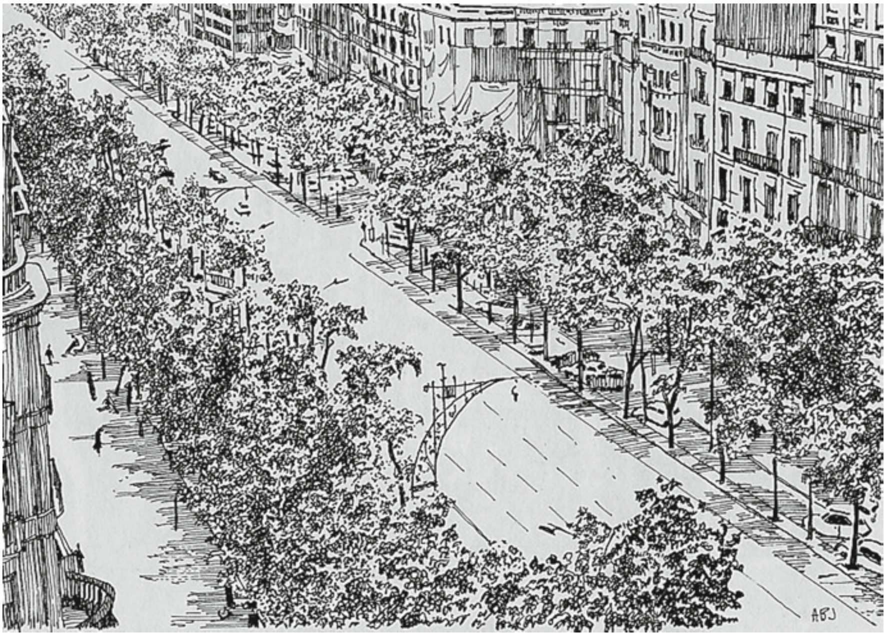

Fig. 46.9 Paseo de Gracia, Barcelona (Source: Jacobs et al. 2002)

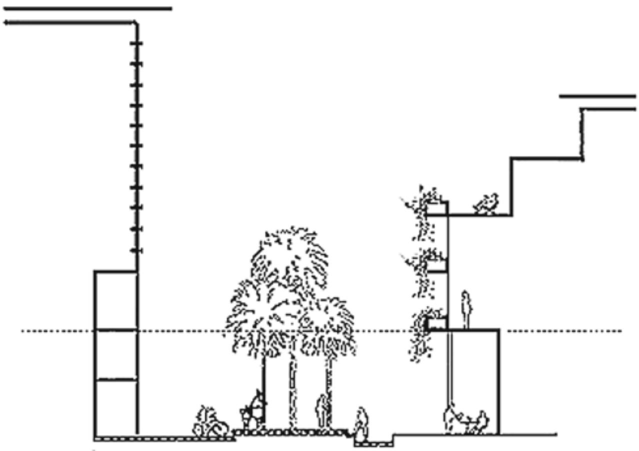

Fig. 46.10 Example of an asymmetrical canyon, combining summer comfort at street level, winter solar access and high density (Source: Toudert 2005)

of existing architectures in hot, dry climates and proposes varied design possibilities for micro-climate control, including attention to aspect ratios and orientation, tree planting, façade greening and other shading devices for irradiated wall and ground surfaces (see Fig. 46.10).

46.3.5 Building Adaptive Capacity into the Transport System

Transport infrastructure and operations are severely affected by climate impacts. For example, increases in very hot days and heat waves can result in cancellations of air transport operations because of lift-off load limits; they can impact surface transport infrastructure due to thermal expansion in bridge joints or paved surfaces, compromised pavement integrity (for example softening) or rail-track deformities (see Fig. 46.11).

Rising sea levels, combined with storm surges, will cause more frequent interruptions to coastal and low-lying roadway travel and rail services and severe flooding of underground tunnels and low-lying infrastructures. Increases in intense precipitation events will cause weather-related traffic disruption and delays, damage to rail-bed support structures, flooding of roadways, as well as landslides and mudslides that damage roadways and tracks.

The Transportation Research Board (2008) has investigated the most relevant potential impacts of climate change to the US transportation system, and how they will affect the planning, design, construction, operation, and maintenance of infrastructure. It reports that climate impacts will vary by mode of transportation and region of the country, but indicates overall that impacts will be costly in both human and economic terms, and require significant changes to current modes of operation.

Suarez et al. (2005) provides an interesting approach to investigating the extent to which climate impacts give rise to indirect costs due to factors such as delays, detours and trip cancellations. Decisions taken today, particularly those related to the redesign,

Fig. 46.11 A heat wave causing transport chaos as a result of rail line buckling (Source: http://www.worldculturepictorial.com)

location and retro-fitting of transportation infrastructure, will affect how well the system adapts to climate change far into the future. Focusing on the problem now should help to avoid costly future investments and disruptions to operations.

46.4 Conclusions

Global warming is already occurring. Its effects will be increasingly amplified in our towns, where the presence of buildings and pavements, combined with a relative lack of vegetation, exacerbate the risk of flooding and temperature increases. This paper, written as part of the GRaBS project, gives an overview of the complex interactions between climate change and transport systems, addressing the role of transport policies both in mitigating the global effects of climate change and in enabling cities to adapt to expected impacts within the framework of sustainable urban development.

The transport system, like other assets of the built environment, is threatened by climate change must be considered in order to preserve the system. Adaptive responses to variables associated with climate change, such as increased heat, rising sea levels, and higher incidences of flooding, must be integrated into the planning, design and management processes of transport infrastructure.

Policies that reduce automobile dependency are also positive long-term solutions for mitigating climate change, and will involve a rethinking of urban development. A balance must be found between establishing sustainable transport systems which reduce GHG emissions and increasing the resiliency of cities to pending impacts. This balance may be reached by focusing on the creation of medium-density housing, including separate medium-size green spaces, well connected by a dense network of green corridors that provide accessibility by sustainable transport to green spaces and to other urban activities.

Some insight has been provided on the influence that climate change will have on urban travel behaviour, in terms of trip generation, trip distribution and modal choice. The significance of integrated, secure and attractive green infrastructure, used for both recreation and commuting, was emphasized, with street trees and multi-way boulevards offered as two of several examples for achieving this.

In sum, adaptation and mitigation policies must be integrated into win-win solutions which both minimize climate risks while delivering social, environmental and economic benefits. The greening of urban mobility should be supported, both in the sense of favouring the shift towards green (sustainable) modes of transport and in enabling the development and use of green spaces.

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Chapter 47
Urban Green Spaces: Potentials and Constraints for Urban Adaptation to Climate Change

Juliane Mathey, Stefanie Rößler, Iris Lehmann, and Anne Bräuer

Abstract Urban development has to meet the challenge of establishing adaptation strategies in response to climate change. In view of its potential to regulate urban climates, green infrastructure will assume a critical role in these strategies. In addition to their positive microclimatic effects, as a source of cooling in dense, hot cities urban green spaces can contribute to mitigation. They can operate as carbon sinks or can reduce energy consumption for air conditioning by providing shade by urban trees or roof-top greenery. Thus, urban green spaces should be incorporated as a significant component into both adaptation and mitigation strategies. This paper focuses on the potentials and constraints of various types and structures of urban green spaces and vegetation in influencing climatic conditions in urban areas. It examines the ability of urban green spaces to counter the urban heat island effect and other impacts of climate change. The scientific findings discussed are based on urban vegetation analysis and climate modelling as well as analysis of planning approaches and instruments in German cities. They will be analysed in the context of the future relevance of greens spaces, and within the framework of current urban planning and development mechanisms.

Keywords Urban adaptation • Green space planning • Urban resilience

47.1 Creating Resilient Cities by means of Urban Green Spaces

The urban heat island effect is characterised by greater dryness, heat and lower wind strengths in urban areas, compared with their rural surroundings. It is expected that climate change will lead to greater instances of the urban heat island effect,

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lowering the quality of life in urban areas and posing health-related problems. Higher temperatures, varying humidity, wind conditions and other impacts associated with climate change may also prove detrimental to the biodiversity of urban areas, leading to changes in species composition and in vegetation structure. Green infrastructure has a crucial role in providing solutions to some of these problems, particularly in providing natural cooling within dense, hot cities (Bruse 2003; Gill et al. 2007; Endlicher and Kress 2008). In addition, it can contribute to increased air humidity and improved air circulation. These benefits, combined with the fact that urban green spaces may act as carbon sinks, means that green infrastructure addresses both adaptation and mitigation aspects (Wende et al. 2010). This underlines the relevance and importance to integrate green spaces in urban strategies dealing with climate change.

Despite the fact that the beneficial climatic effects of green spaces and vegetation in cities have been understood since the 1980s, the necessity of incorporating urban climate and green spaces issues into urban planning has been overlooked, and is now starting to gain prominence in current debates. There are several weaknesses currently preventing the green infrastructure approach from progressing. These include a lack of detailed knowledge concerning the climatic effects of specific urban vegetation structures and their effects within the urban green space system and the fact that conservation and green space planning are subject to a diversity of (conflicting) political and planning demands and visions.

47.2 Research on the Role of Urban Green Spaces Under Climate Change

Against this background, the Leibniz Institute of Ecological and Regional Development Dresden (IOER) has carried out a research project in collaboration with the Meteorological Department of the Technische Universität Dresden to investigate the role of urban green spaces for cities under climate change. The project was funded by the German Federal Agency for Nature Conservation with funds from the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. Its goal was to develop transferable adaptation strategies for the planning and management of green spaces in cities, with the aims of improving the quality of life for urban inhabitants and protecting urban biodiversity.

The research is based on the analysis of urban vegetation structures and on climate modelling, as well as an analysis of planning approaches and instruments in German cities. The starting point of these investigations has been the assumption that correlations exist between the structural parameters of urban green spaces (such as green volume, vegetation height, size etc.) and climatic regulatory effects. To evaluate and quantify these benefits, a method has been developed to describe the urban vegetation structure for the entire city based on city-wide urban biotope mapping after Schulte et al. (1993) (Arlt et al. 2005). Fifty-seven urban vegetation structure types (UVST) have been identified as homogeneous units according to vegetation structure (see Fig. 47.1). Their green volume, sealing proportion etc. have been characterised by means of representative examples.

This approach not only incorporates urban green spaces, but also built-up areas with their vegetation structures, and makes it possible to specify the entire vegetation inventory of a city in both quantitative and qualitative terms. Based on this detailed data, various methods of climate modelling can be adopted to determine and describe the climatic regulatory effects of single urban vegetation structure types (Bruse and Fleer 1998) as well as the whole urban green structure of a city (Goldberg and Bernhofer 2001). This approach can thus inform recommendations for the planning and realisation of urban green spaces in order to ensure resilient cities.

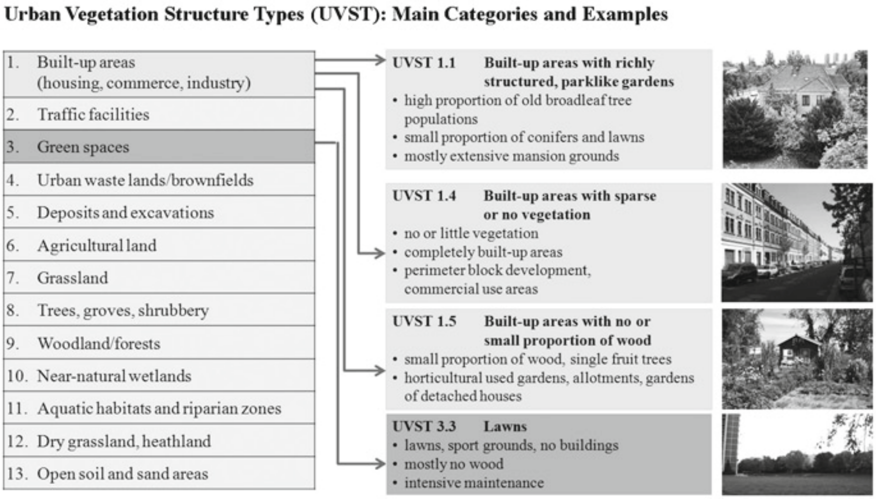

Fig. 47.1 Urban vegetation structure types (UVST), main categories and examples

47.3 Urban Green Spaces and Their Potentials for Adaptation to Climate Change

Initial results of the research project, derived from structure analysis and climate modelling, make clear that urban vegetation structure types differ greatly in their potentials to influence the micro-climatic situation. A temperature modelling for selected urban vegetation structure types with ENVI-Met showed that at 2 p.m. on a hot summer's day the potential cooling effects in comparison to an asphalt covered reference area can differ by 0.1–2.4 K air temperature (measured at a height of 1.20 m).

In built-up areas the strongest cooling effects of 0.7 K can be expected in extensively greened residential areas. A wide range of possible cooling effects can be achieved in urban parks, ranging from up to 2.4 K in those with dense tree stocks, such as cemeteries, to an average of 0.8 K in typical neighbourhood parks with a high proportion of lawns and less dense tree stocks (Rößler et al. 2010). The ability of urban green spaces to regulate the urban climate varies over the course of the day. During daylight hours the effects are governed by the interaction of direct sunshine, shade and wind strengths.

Due to vegetative shade, evaporative cooling and low heat storage (from daytime irradiation), the cooling effect of parks is much higher than that of their built-up surroundings, especially in the evening and at night. During the night, open unsealed areas have a high cooling effect. Densely built-up and sealed areas are heat stores and thereby emit heat to their surroundings, which is especially notable at night. The heat storage can be lessened by means of greened walls or roof-top greenery.

47.4 Application of Modelling Results Within Green Space Planning

Based on the structure analysis and climatic modelling described above, some tools for green space planning can be offered to help the adaptation to climate change. Firstly, the characteristics and climatic benefits of all 57 urban vegetation structure types has been summarised in tabular form. These tables of characteristics contain information on vegetation, land use and built-up structures as well as descriptions of climatic effects and indications on potentials for biodiversity. Using this information it is possible to base planning decisions on climatic relevant parameters of green spaces and the potentials of different urban vegetation structures.

A further important aid to planning decisions is the simulation of climatic effects through various urban land-use scenarios. For example, it is possible to simulate potential negative effects of increased urban density or the positive effects of more extensive green spaces. On the one hand scenarios have been developed to deal with processes of urban shrinkage as well as to reach better environmental quality and improved quality of life. These foresee the designation of new green spaces, the increased greening of current residential areas or the re-structuring and expansion of green volumes in current green spaces. On the other hand against a backdrop of urban growth and the intensive use of inner city plots, scenarios have been developed which can illustrate increasing densities in built-up areas or the re-assignment of disused or green spaces as land for construction.

Knowledge of the climatic repercussions of diverse urban vegetation structure types can be of assistance to urban planners to ensure a climate-adapted city. They can obtain insights into where and which type of green spaces should be retained or developed. One example scenario of urban development is illustrated in Fig. 47.2, where the designation of new residential areas entails the sealing of lawns in a neighbourhood park. The model shows that such a plan, when implemented, would lead to a maximum temperature increase of 0.5–1.0 K. The surrounding buildings would suffer from higher temperatures, particularly on summer nights, while residents would no longer be able to enjoy the green spaces to cool down and for relaxation.

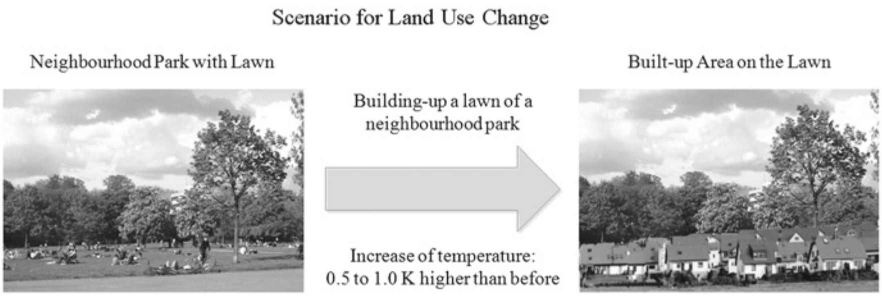

Fig. 47.2 Scenario for land use change in a neighbourhood park (Photo: C. Smaniotto Costa, Collage: I. Lehmann)

47.5 Conclusions for Urban Green Space Planning

Based on the findings of the research project, several conclusions regarding the positive effects of green spaces on urban climate can be drawn. Improved climatic conditions can be achieved using a network of distributed green spaces throughout the city. A richly structured system of many parcels of interconnected green spaces, supported by unrestricted cold air corridors from outlying areas, can positively influence the entire urban micro-climate. Large and coherent areas with high density of vegetation have a stronger cooling effect than small areas with lower density of vegetation. For example, cooling effects are especially high in large parks or areas of woodland.

However, for the potential alleviation of climatic conditions, the structure of vegetation and the characteristics of each green space are even more important than mere size. The vegetation structure of urban green spaces can differ greatly, leading to (small-scale) differences in the potential for cooling. In terms of planning goals, a decision must be taken in each case whether a daytime or night-time cooling effect is desired. This will greatly depend on the function and use of each space. For example, the shade offered by vegetation is in high demand during hot summer days.

In future, the provision of green space systems to alleviate climatic conditions will increasingly require the careful selection of plants according to their ability to cope with drought and high temperatures as well as good management of green spaces. Dried out lawns or trees with an insufficient leaf coverage are unable to realise their potentials for cooling. It is important that planners are aware of the opportunities which urban green spaces offer in adapting to climate change, as well as the physical limitations which exist in terms of their size, vegetation structure, position within the urban green system and the built-up surroundings. The cooling capacity and climatic regulation functions of urban green spaces require particular consideration in terms of their use and maintenance.

To optimize the contribution of green space development towards the goal of resilient cities, the topic must be examined at different planning levels. At the regional level, a city-regional green space system with green belts and corridors for cool air flow should be allocated to ensure green pathways from the surroundings into the city. In the urban fringe, open areas must be retained to allow the accumulation of cold, fresh air. At the city level, strategies for the development of an urban green system have to be implemented according to ecological and social needs. The distribution, connection and dimensions of urban vegetation structure types can vary in urban green space systems. At the city-district level and below, attention must be paid to the design, ensuring an optimal shape, structure of vegetation, function (use) and maintenance of individual green spaces to guarantee the provision of ecosystem services. In Germany, the political instruments for urban planning and nature preservation support the implementation of green spaces as part of adaptation strategies (ARL 2009; Rannow and Finke 2008).

Finally, urban green space development must also be viewed in relation to other challenges of urban development. In addition to potential synergies, there are areas of potential conflict regarding the aims of green space development. For example, urban vegetation can support mitigation strategies by functioning as a carbon sink and to provide shade. On the other hand, the objective of achieving carbon reduction by realising more compact, dense urban areas may contradict the aim of expanding urban green systems. The greening of urban wastelands is another potentially contentious example. While potentially helping to regulate the urban climate, and provide diverse ecological, social and aesthetic benefits (Mathey et al. 2003; Mathey and Rink 2010) the use of urban wastelands for new construction (in order to avoid urban sprawl) stands in conflict with its greening. The aim of enhancing biodiversity can lead to conflicts between inner-city ecosystems and the protection of natural areas in the urban fringe.

Among the examples mentioned above, the protection and creation of urban green spaces versus the goal of realizing more compact cities is the most contested. Although these opposing goals cannot be easily reconciled, one possible solution could be qualified or double internal development, which has the aim of protecting green spaces in the urban fringe while improving the environmental quality and quality of life for citizens by means of green spaces (BfN 2008). This process sees the re-greening of wasteland and the development of green spaces as valid alternatives to new construction on urban wastelands. Urban green spaces have the potential to buffer climate related impacts in cities, if green space planning is incorporated as a significant component of urban adaptation strategies.

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Chapter 48
Urban Climate Framework: A System Approach Towards Climate Proof Cities

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Abstract The urgency of climate proofing urban areas is increasingly recognized and various adaptation and mitigation measures are being developed. However, to combine these measures into comprehensive strategies is a challenge. The incorporation of climate change issues in day-to-day urban development requires better understanding of the urban system and the relations between climate and non-climate urban issues. In this paper we describe a theoretical framework and practical tool to get a grip on the urban complexity and climate change effects: the Urban Climate Framework (UCF). The UCF approach is based on different system approaches and aims to expose underlying relations in the urban system. This enables better understanding of second order effects of climate change impact and the identification of robust strategies to balance between mitigation and adaptation. The framework is developed in the context of adaptive governance and can be used to structure information of different fields of knowledge and stakeholder groups. The UCF serves as a knowledge brokerage tool to incorporate climate change in the complex processes of urban development, which can be used by researchers, policy makers, urban planners and designers.

Keywords Adaptive governance • Climate proof cities • Knowledge brokerage instrument • System approach

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48.1 Introduction

Both the major contribution of cities to global climate change and the urgency of climate proofing urban areas are increasingly recognized (VROM 2008). Many cities are struggling with the new tasks of how to prevent further climate change (by CO_2-reduction) as well as how to deal with the effects of climate change such as heat, water excess and drought and their secondary effects. Such effects will influence the physical characteristics and functions of cities, affecting various economic, social and health issues (Kuypers and de Vries 2008; Döpp et al. 2009) (see Fig. 48.1). Research is currently being conducted in national and local research programs (e.g. Knowledge for Climate 2010) regarding the consequences of climate change at city-level, and finding appropriate solutions to maintain safe, liveable and healthy cities. It is clear that both adaptation and mitigation need to be incorporated into sustainable urban development, preferably in an integrated manner. However, the development of comprehensive strategies and the actual implementation of measures are still great challenges in the dynamic and complex context of cities.

Successful incorporation of climate proofing elements requires 'mainstreaming' (Klein et al. 2007) of mitigation and adaptation into urban development and design. In order to find relations between general urban issues and those specifically related to climate change, a good understanding of the urban system as a whole is required. Furthermore, combining the knowledge of urban planners, policy makers, scientists

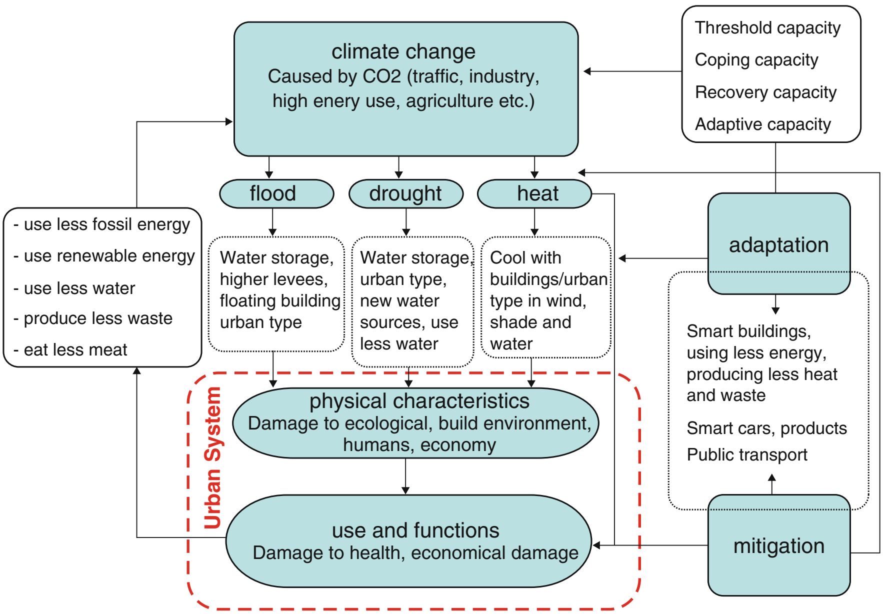

Fig. 48.1 Schematic representation of climate change impact on the urban system, and (examples of) adaptation and mitigation measures to be taken

and other actors is crucial to finding effective integrated solutions. Existing decision support tools and methodologies for developing climate change strategies seem to focus on measuring impacts and the modeling of scenarios (Sheppard and Shaw 2007). These tools lack the ability to assist actors at different scales in the formulation, implementation and evaluation of climate adaptation and/or mitigation strategies (Laukkonen et al. 2009). Moreover, existing models are not designed to facilitate stakeholder participation.

TNO has developed a method based on the system approach to support the incorporation of climate proofing in the day-to-day practice of city building: the Urban Climate Framework (UCF). The Urban Climate Framework helps cultivate an understanding of urban systems in relation to climate change impacts, and facilitates dialogue between various stakeholders in order to find win-win solutions. This paper explains the construction of the Urban Climate Framework both as a theoretical model and practical tool. The municipality of Rotterdam acted as consulting partner to support the application of the UCF.

48.2 Adaptive Governance and System Approach

Cities are considered to be complex adaptive systems (Benton-Short and Short 2008). They are dynamic, connected and open systems that continually evolve in response to internal interactions and external factors (Holling et al. 2002; Bai 2003). In order to deal with climate change in these complex environments, there is a need for adaptive co-management or adaptive governance (Folke et al. 2005; Armitage et al. 2007). This involves the 'evolution of new governance institutions capable of generating long-term, sustainable policy solutions to wicked problems through coordinated efforts involving previously independent systems of users, knowledge, authorities, and organized interests' (Scholz and Stiftel 2005). Adaptive governance in cities requires a thorough understanding of urban systems as well as input from multidisciplinary and multi-perspective stakeholder groups. The UCF is developed to facilitate the process of gathering and combining information in an effective way.

A system approach makes it possible to understand the urban system and the issues of climate change in relation to each other. The use of system approaches emerged in the 1950s as a reaction on the reductionist approach. Following reductionist approaches, issues were de-contextualised and reduced to their essences; as a result, complexities were over-simplified (Flood 2001). As Einstein advised: 'make your object of study simple as possible but no simpler.' The system approach is a method for studying phenomena as emergent properties of an interrelated whole, in interaction with their surroundings (Heylighen 2000). This makes the object of study simpler, but still enables meaningful analysis of issues that deal with elements of differing natures. The latter is specifically interesting in the context of cities, where the mixture of elements such as urban structures and users can be conceived as part of the climate problem as well as part of the solution.

The UCF is built upon several system approach methods. Several principles have been established in order to investigate the city as a complex adaptive system (including impacts of climate change) and to act as a knowledge brokerage tool. These include commitment to a simple but comprehensive structure, offering insights into the relations within the city and possible interventions, and easily combining information of differing natures. Elements were used from the following four system approach methods:

- *DPSIR framework* (EEA 1994): a causal framework to assess interactions between social and environmental systems, based on driving forces, pressure, state, impacts and response;
- *SCENE-model* (Rotmans and Dowlatabadi 1998; Grosskurt and Rotmans 2005): a supporting tool for regional sustainability analysis, based on stocks and flows in the social, environmental and economic sustainability capital domains;
- *Layers approach* (Hoog et al. 1998; van Schaick and Klaasen 2007): a conceptual framework to guide spatial planning policy;
- *Vulnerability approach* (e.g. De Graaf 2009; Brooks 2003): a general approach to identifying vulnerabilities within a system and its ability to deal with impacts, based on concepts such as threshold capacity, coping capacity, recovery capacity and adaptive capacity.

48.3 Urban Climate Framework (UCF)

The Urban Climate Framework can be described as a four-step approach and a practical tool that facilitates stakeholder participation. The practical tool consists of a blank table that needs to be filled in by stakeholders (see Table 48.1). Elements along the X axis of the UCF table represent the basic four-step system approach that is derived from DPSIR (see Fig. 48.2). Elements along the Y axis represent stocks (based on the SCENE-model) of the urban system, structured according to the layer-approach. In this paragraph, a brief description of the table construction is given, and the four steps of the system approach are described in relation to the table.

Three key urban functions operate as the starting point for the construction of the UCF-table for maintaining healthy and liveable cities, including living, working and amenities. We identified their main stocks in Fig. 48.3 and ordered them according to six physical layers (based on a layer approach) from high to low dynamics: users, metabolism, occupation, public space, infrastructure and underground. This structure enables a clearer understanding of the scale of impact that climate change has on each layer, and provides an indication of the ease and speed with which changes related to interventions, such as those related to adaptation to climate change, can be achieved. For example, adaptation measures like simple changes in behavior (user layer) may be achieved within a shorter timeframe and with less investment than many infrastructural adjustments (infrastructure layer).

Table 48.1 The Urban Climate Framework knowledge brokerage tool (Source: TNO)

System approach / Layer	Stock	Flow	State	Pressure Climate (drought, heat, flood) From system/ urban tasks	Vulnerability	Impact	Response Mitigation interventions	Response Adaptation interventions -Threshold -Coping -Recovery -Adaptation
Users	Social structure							
	Social behaviour							
	Labour productivity							
	Labour capital							
City metabolism	Energy							
	Food							
	Water							
	Waste							
	Air							
	Material							
	Products		System		Problem		Interventions	
Occupation	Offices		analysis		analysis			
	Housing							
	Utility							
	Culture							
Public space	Living environment							
	Culture							
	Nature							
Infra structure	Mobility							
	Network			Evaluation				
Underground	Network							
	Soil conditions							

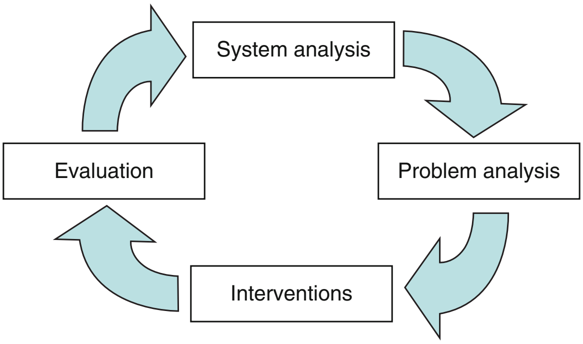

Fig. 48.2 Scheme of the system approach of the UCF

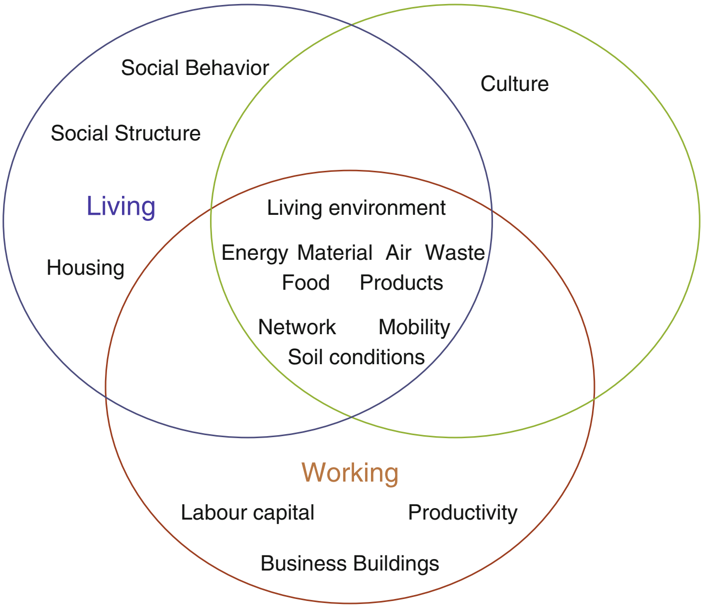

Fig. 48.3 Essential urban functions and required stocks

The system analysis aims to provide a clear overview of local conditions within the current state of an urban system as well as the future pressures that the system will be subjected to. In the UCF table information for system analyses is placed in the columns s*tate* and *pressure*. Relevant questions in the system analysis are: what are the social, physical, chemical and/or biological characteristics and current conditions of the different stocks? The representation of the current situation of the different stocks within the layers offers insight in the qualities and tasks within these layers. For example, *public space* in post-war expansions in Rotterdam is considered to be too large and anonymous. Concerning the *housing stock* in these areas there is ground-bound houses. The second part of the system analysis is a description of the physical and social-economic pressure for each stock. Here, the connections between climate impact and contemporary urban development can be made since both pressures are ordered by stocks right next to each other. In examples of post-war areas within Rotterdam, pressures are formed by climate change-induced flooding, which disrupts the artificial water system built in these areas. Socio-economic threats in this case result from shortcomings within the housing sector as well as uncontrolled large green areas.

Relevant questions in the problem analysis are: how vulnerable are the stocks for the effects of climate change and/or social-economic pressures, what is the potential impact on the urban system? This information is collected in the table columns *vulnerability* and *impact* respectively. The impact of climate change in one stock might result in negative results in other stocks as well. These secondary effects are placed in the *flow* column of the relevant stock. For example, vulnerability of post-war areas in Rotterdam relates to the properties of public space and buildings (damaged by water), and the social structure and living qualities of the areas. They are negatively influenced by insufficient housing and uncontrollable public space. The impacts on the stocks *housing* and *public space* in Rotterdam have a secondary impact on the stock *social structure* and *living qualities*.

Understanding the vulnerability of the system is useful in the third step of intervention (*response* column). Adaptation options should be based on a strategy of lowering vulnerability by increasing the threshold capacity, coping, recovery, and/or adaptive capacity. The results from the system analysis, problem analysis and interventions to different threats can be bundled per layer, i.e. the space where they can be solved. This illustrates the connection between climate and non-climate threats per layer and assists the development of integrated solutions. Examples of mitigation interventions in the post-war area in Rotterdam are policy measures like reduction of fossil energy use, stimulation of renewable energy, water conservation and waste reduction. Addressing socio-economic problems would require rebuilding the area completely with housing and proper public space. Climate adaptation means adjusting the water system, introducing more water storage to prevent flooding and adjusting buildings and public spaces to current demands.

The fourth step of the system approach cycle is the evaluation phase. The aim of this step is to determine the both direct and indirect influences of the proposed mitigation and adaptation measures on other elements (stocks and layers) of the city, including positive and negative effects. If interventions have significant influence on other stocks, these effects are placed in the column *flow* of the relevant stock. Within the cyclic system approach this can be considered as part of the state in a new system analysis. Conflicting and synergetic measures can be found within a single layer. For the post-war areas in Rotterdam, it is clear that some tasks in the *public space* can be combined with climate tasks, but effects on the stock *social structure* must also be taken into consideration. Furthermore, rebuilding the area completely offers opportunities to take various climate measures.

48.4 Usability for Public Service Provision in Rotterdam

In order to examine the applicability of the UCF, interviews were conducted with several municipal service departments in Rotterdam including the office of municipal real estate development (OBR), the regional environmental agency of local and regional authorities in Rijnmond (DCMR), the departments for urban planning, housing (dS+V) and public works (Gemeentewerken), a housing corporation and the city administration. Interviews focused on the usability of the UCF as a practical tool for the specific departments and services, and were used in order to improve the content and structure of the supporting table.

All municipal services indicated a need for a wider perspective on urban development and the integration of climate issues. The scope of traditional sectoral approaches is often too narrow to produce well considered decisions (e.g., environmental impact assessments). The UCF was seen as an opportunity to bring more disciplines together, and as a discussion tool for people of differing professional backgrounds. There was a particular interest in linking physical and social components of urban development and climate change issues. Social developments are barely considered in structural investments, and there is room for improvement in this area. Combining physical and social (non) climate issues in the UCF approach could help to make this connection.

A problem in many sectors is the inability to appreciate the complexity of the climate issue, in terms of components and timeframe. Due to these complexities, sectors remain within their area of specialization. The UCF as a tool for analysis could help foster cross-sectoral collaboration. Public services are looking for new cooperation and communication strategies in order to jointly provide and combine relevant information on climate and environmental aspects in development projects. The use of the UCF table in a multi-disciplinary interactive setting is seen as a powerful tool for sharing knowledge and overcome the ignorance that still exists, both on the coherency between different domains and on the (indirect) effects of and responses to climate change.

According to interviewees the UCF table offers a good basis for organizing information in interactive processes. There must be a clear distinction between the use of the UCF table as knowledge base or as discussion tool, as this distinction can also be interpreted as objective and subjective data. A clear explanation about the context and purpose of the framework before use is necessary, so that users unfamiliar with the data and system approach can work with it. The inclusion of more facts and figures such as maps or flowcharts will further strengthen the UCF as a tool.

Interviews showed that all public services in Rotterdam are struggling with the complexity of incorporating climate issues into urban development, and expressed a need for methods or instruments to support this process. The systematic, integrated approach of our framework was received positively and its further development as a practical tool was strongly encouraged. Several internal and combined sessions will be organized with the public services in Rotterdam, in order to use and further develop the framework in an interactive way.

48.5 Conclusions

The UCF is a system approach wherein all components of urban systems are brought together in a simple and comprehensible way. The UCF organizes information of different types to enable the visualization and comparison of possible mechanisms. It further offers a place-based integrated assessment of mitigation and adaptation measures. The UCF facilitates multi-level stakeholder participation for a shared monitoring of current conditions and projects future developments. It connects the tasks common to climate and city development, and incorporates contextual uncertainties. The UCF is not developed to make long-term predictions or to describe quantitative scenarios. It is specifically a database and analysis tool that presents a moment in time and that can be used to find balance between measures for a certain end goal or to look into the results of a specific scenario.

The UCF can integrate the climate task into existing urban planning by through two mechanisms. First, the framework can function as library of different types of information ordered in a cause-and-effect chain. A new state of the system is determined after each cyclic analysis. For work in progress, the library can be used to provide essential context for projects and give insight to their complexity; for urban designers it constructs the background and greater context of their projects. For policy makers, the information can be used to balance different influences on the urban system and to steer policy directions. The second application for the UCF is as a knowledge brokerage tool to support interaction between stakeholders and/or experts. The framework allows to place different views on matters next to each other and to establish better understanding and cooperation between stakeholders and/or specialists. The fact that the information in the table is based on value judgments of the observer is very useful in this case; the framework does not model an objective truth but facilitates debate amongst the stakeholders because it will make their different viewpoint very clear.

Results from the first tests to the usability of the UCF approach by the interviews in Rotterdam and desktop studies are promising. However, further development of the practical tool in cooperation stakeholders is required. Several internal and combined sessions will be organized with public services of Rotterdam and perhaps with other municipalities. Other work that will be done in the development of the UCF is related to dynamic system modeling, and the possibilities of including time-related models in the framework.

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Part VI
Reality Check – Adaptation on the Ground

Chapter 49
Introduction: Reality Check – Adaptation on the Ground

Olivia Tusinski

While adaptation is starting to become recognized as an essential response to the expected impacts of climate change, few cities have initiated early and sustained adaptation commitments. Even as many cities undertake a range of mitigation projects, from emissions monitoring to waste-to-energy conversion, the approaches, tools and methodologies related to adaptation – even the definition of the term itself – remain somewhat obscure to many cities.

This may be due to the relatively new appearance of adaptation on the international agenda, which has not yet been clearly defined to facilitate direct access to funding for local entities. It could also be related to the long-term nature of adaptation commitments, which have proved less attractive to investors and pose difficulties for implementation within the time-frame of most elected officials.

There is also the perception that condoning adaptation activities is to accept 'defeat.' Where the topic has successfully entered local climate agendas, experts and practitioners have battled against the perception that adaptation may undercut mitigation – draining time, staff and other resources from activities that target climate change at its source. Regardless of this perception, however, climate-related impacts do persist, with cities widely acknowledged as being particularly vulnerable.

The Reality Check Workshop series held at the Resilient Cities 2010 Congress – from which the following contributions result – was conceived to address the gap between adaptation needs and practice, and in recognition of the need to bring local actors to the forefront in identifying the factors that affect strong local leadership. The series provided an opportunity for city delegations to present their own projections, strategies and plans while enjoying a platform from which to address tough questions, such as:

- Should existing infrastructure be repaired or should cities re-build in different locations?

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- Should the construction of dams increase or should flood plains be emptied and restored?
- Should water supplies be centralized and brought in from remote sources?

The 2-h sessions offered an in-depth look at ‘adaptation on the ground,’ told from the perspective of a variety of local actors working for and with cities. Because the workshops involved participation from city managers, councilors, land use and infrastructure planners, and experts from local universities and institutions, it became more than just a series of individual presentations from experts; more importantly, it fostered an atmosphere of collaboration where delegates could learn from each other and from the feedback and observations of an audience consisting of members of the international ‘adaptation community.’

The cities of Dhaka, Quito, Durban and Miami-Dade County were the first to participate in this annual series. Specially selected to represent a diversity of geographical locations, each city presented a wide array of adaptation challenges and organizational approaches to pending climate impacts. Several of the cities share similar threats. Dhaka, Durban and Miami, for instance, face rising sea levels compounded by severe flooding, saltwater intrusion, heat stress, coastal erosion, and loss of biodiversity. Quito, which is located inland and at high altitude, is experiencing a diminishing water supply, as well as sanitation and infrastructure risks associated with uncertain precipitation patterns.

The stakes and scale of climate impacts in each city also vary. As Dhaka is the economic center of Bangladesh, with a high concentration of people, enterprise and government offices, the combined threat of sea level rise and increased rainfall could result in the displacement of a large proportion of the national population, damage to infrastructure, and increases in vector borne diseases. Such perils also threaten the functioning of government and economic productivity on a national scale.

Impacts for Durban include health costs associated with water-borne disease and damages to infrastructure. The sustainability of the city’s established local property market is also threatened. Miami’s concerns centre mainly on the provision of adequate water for consumption and irrigation due to the threat of sea-level rise and salt-water intrusion. This also threatens one of the area’s strongest economic bases of seaside tourism. Finally, Quito must find innovative and affordable solutions for its citizens while addressing informal hillside developments affecting a large proportion of the city’s inhabitants.

Dhaka, Quito, Durban, Miami-Dade County also represent different political and organizational approaches to adaptation. Each city has a unique relationship with its regional and national government, and each demonstrates varying degrees of experience in facilitating inter-city and regional partnerships.

Presentations from the Dhaka delegation show that urban adaptation plans have been subservient to policies generated at the national level, which have tended to overlook adaptation needs in urban contexts. Quito, on the other hand, enjoys a strong and productive relationship with its national Environment Ministry, receiving funding support and collaborating in international climate negotiations. Strong leadership at the city-level has resulted in a dedicated Climate Change Unit, which has forged a city climate change strategy and initiated regional partnership for sharing best practices.

Miami-Dade County is less involved with higher tiers of government, collaborating occasionally with national agencies on the development of coastal initiatives and tools. Like Quito, it has benefited from strong local leadership, which has led to the development of a Climate Change Advisory Task Force comprised of experts in social, economic, and environmental science fields. Finally, 'adaptation champions' within Durban's municipal departments have initiated adaptation projects including reforestation projects, pilot green roofs, and sea level rise modeling without legal mandate or formal funding from higher tiers of government.

The first Reality Check Workshop series has illustrated different facets of the need to address urban adaptation, and has shown how adaptation approaches can be tailored to fit multiple urban contexts. The experiences of the participating cities highlight the range of local approaches to issues such as institutional partnerships, sub-national and national cooperation, funding mechanisms and arrangements, and public-private cooperation. Discussions emerging from these sessions have provided further insight into the significance of institutional maturity, support from national and provincial entities, and cross-departmental collaboration in furthering urban adaptation at the local level. The following chapters provide a detailed look at the issues touched on in this introduction. We hope these papers will provide inspiration and guidance for local authorities looking to address this crucial piece of the climate puzzle.

Chapter 50
Preparing for Climate Change While Advancing Local Sustainability: A Closer Look at Miami-Dade County, Florida, USA

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Abstract Miami-Dade County is a diverse, low-lying county of approximately 2.5 million inhabitants, situated along the subtropical stretches of the southeastern United States. Situated at the tip of a peninsula, just feet above sea level, Miami-Dade County has long been aware of its acute vulnerability to climate change, particularly sea level rise. In this regard, Miami-Dade County began analyzing and implementing mitigation strategies decades before 'climate change' and 'sustainability' became mainstream, and was one of the first local communities to begin actively planning for climate change. Through multiple partnerships and collaborations, the County has well established itself as a leader, and has been actively moving forward to make the community more sustainable and more resilient to existing and future projected climate change impacts. The County has taken active steps to engage and leverage support at the local, regional, state, and federal levels. This multiple level stakeholder engagement is one of Miami-Dade County's most valuable tools in becoming a more climate resilient community.

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50.1 Introduction to Miami-Dade County

Miami-Dade County is a dynamic, economic and culturally diverse coastal community in southeastern Florida. Bordered by two national parks, including Biscayne National Park and Everglades National Park, it is the most populous county in Florida, and the ninth largest county in the U.S. with a current population of 2.5 million, projected to increase to 3.2 million by 2030 (Fig. 50.1).

The County is comprised of 35 municipalities and a large unincorporated area. There are 156 nationalities represented in the County, with approximately 50% of the residents being foreign born, and over 100 different languages spoken. Within the County, 62% of the population is Hispanic, 18% are non-Hispanic White, and 18% are non-Hispanic Black. Due to this diversity, Miami-Dade County regularly conducts business in three different languages – English, Spanish, and Creole. Economically, Miami-Dade County's annual Gross Domestic Product is approximately $111 billion – 90% of which is from the private sector and just less than 11% is from government.

Regarding governance, Miami-Dade County has a two tier form of government with the County providing regional services, as well as city-type services, to a large

Fig. 50.1 Downtown Miami-Dade County (*background*) and residential communities (*foreground*) located adjacent to Biscayne Bay (Miami-Dade County photograph)

unincorporated area, as well as to some of the 35 separate municipalities within the County. These services range from public housing and utilities to public safety and environmental protection. The County Mayor is elected County wide and is the administrative head of county government. Mayor Carlos Alvarez, the current County Mayor, appoints all department directors. In addition to a Mayor, the County has also a Board of County Commissioners (BCC), which consists of 13 members elected by districts. The Board of County Commissioners is the legislative branch of county government. The County's budget was approximately $7.8 billion in Fiscal year '2009–'2010, comprised of a $4.7 billion operating budget and a $3.1 billion capital budget.

50.1.1 A History of Environmental Leadership

Miami-Dade County has been leading the environmental charge, both domestically and internationally, for over 20 years. In fact, the Board of County Commissioners has passed 99 pieces of sustainability legislation since 1991, covering climate change, energy and water efficiency, alternative energy and fuels, green buildings, and green jobs. Beginning in 1990, County representatives played an instrumental role at the United Nations World Congress of Local Leaders and aided in the formation of a global organization designed to ensure that the local voice was integrated into international policy making. This organization was created in 1990 as the International Council for Local Environmental Initiatives and is now known as ICLEI – Local Governments for Sustainability (ICLEI). As an inaugural member of ICLEI, Miami-Dade County quickly began participating in the Cities for Climate Protection (CCP) campaign aimed at reducing greenhouse gas emissions. By 1993, the County had adopted its Urban CO_2 Reduction Plan, which led to a reduction of approximately 34 million tons of carbon dioxide (CO_2) equivalent emissions.

Other notable environmental accomplishments in Miami-Dade County include:

- Creating the Climate Change Advisory Task Force (CCATF) in 2006 (discussed further in Sect. 50.3).
- Joining the Chicago Climate Exchange (CCX) in 2007.
- Becoming a pilot community in ICLEI USA's Climate Resilient Communities adaptation program (2007).
- Creating an Office of Sustainability in 2007.
- Establishing a Sustainable Buildings Ordinance and Program in 2007 to advance sustainable and environmentally responsible planning, design, construction and operation of the County's buildings.
- Committing to the "Cool Counties" goals and objectives, to reduce greenhouse gas emissions by 80% by 2050.
- Assisting in the establishment of the Southeast Regional Climate Change Compact, which aligns four Counties in south-eastern Florida to collaborate on both mitigation and adaptation efforts.

50.2 Climate Change and Miami-Dade County

As a coastal community located at sea level, with typical land elevation only 3–10 ft above mean high water, Miami-Dade County is acutely aware of the dangers posed by a rising sea. In fact, in 2007, the Organization for Economic Cooperation and Development (OECD) identified Miami-Dade County as globally having the highest amount of vulnerable assets exposed to coastal flooding (for the 2070s) with a projected potential cost estimated of approximately $3.5 trillion (Nicholls et al. 2007). According to local NOAA tide gauges, the sea has risen 0.78 ft in the last 100 years, which translates to approximately 2.39 mm/year (NOAA 2009). Many scientists believe this rate may dramatically increase due to polar ice cap and glacial melt, in addition to thermal expansion resulting from increased ocean temperatures. The resultant sea level rise is expected to exacerbate coastal and inland flooding, as well as erosion, which the region is particularly vulnerable to along the beaches (as illustrated in Fig. 50.2), coastal habitats, and within the Everglades. The County currently spends approximately $6 million annually in beach restoration efforts, which is only expected to increase as climate change occurs.

In addition, sea level rise could also lead to increased storm surge damage, population displacement, damage to infrastructure, and the spread of infectious diseases. It is important to note that at-risk infrastructure includes utility infrastructure along the coast such as water treatment plants, electric plants, transportation corridors, and landfills, all of which provide critical municipal services. Furthermore, storm

Fig. 50.2 Man walking along eroded beach on Miami Beach (Miami-Dade County photograph)

surge inundation and high wind impacts from tropical storms are additional issues of concern.

Sea level rise also poses many significant water-related challenges for Miami-Dade County. The substrate in the Southeast Florida region is composed of porous limestone which is very transmissive, allowing water to move freely between the pores of the rock underground. At present, the County's sole source for drinking water supply is the Biscayne Aquifer, located just a few feet below the ground surface. Because of the porous nature of the substrate, the Aquifer is not only susceptible to contaminants, but is also hydrologically connected to the ocean and therefore susceptible to saltwater intrusion. As sea level rises, hydrostatic pressure will cause the saltwater front to move further inland, threatening contamination of drinking water wells. An example of this threat can be seen in the southeast region of the County. Although there are many factors believed to be contributing to this particular example, sea level rise is expected to exacerbate this overall threat to the community. The local substrate and water table also pose difficult challenges in regards to protecting the surrounding communities from flooding. As sea level rises, the ground water table will rise closer to the surface, reducing the capacity to absorb storm water and run-off during heavy rain and storm surge events, as well as progressively compromise the effectiveness of the gravity-driven wastewater and storm water infrastructure. Furthermore, the porous nature of the substrate also precludes traditional methods of constructing barrier walls to stave off rising ocean waters.

Miami-Dade County will also likely experience temperature changes in the future. It is projected that the south-eastern United States could experience an increase in temperature anywhere from 4.5°F to 9°F in the coming century, depending on the IPCC greenhouse gas emissions scenario utilized for the projections, as per the Special Report on Emissions Scenarios (SRES) (Karl et al. 2009; Nakićenović and Swart 2000). This temperature change will likely manifest itself as an increase in the number of days over 90°F, with the greatest temperature increases expected during the summer months (Karl et al. 2009). Increases in temperature are likely to lead to more heat-related illnesses and deaths, encourage the spread of vector-borne diseases (e.g., Malaria and West Nile), enhance the likelihood of drought, lead to an increase in energy demand, and have significant impacts on native plant and animal species.

Changes in precipitation patterns are also projected to affect Miami-Dade County's climate. Since the early 1900s, South Florida has experienced a nearly 10% drop in precipitation in the spring, summer and fall. Local data indicates that there has been an increase in heavy downpours in the region, and a 2009 report by the Florida Oceans and Coastal Council indicates this trend may increase and combine with longer dry spells (or droughts) in between. Changes in precipitation can increase the likelihood of flooding and drought, both of which would have detrimental impacts on the County's water quality and supply. An example of this was seen during the period of December 2009 through February 2010, which was the driest winter on record in Miami and Fort Lauderdale, where rainfall amounts during the 3-month period were 0.74 and 0.39 in., respectively (NOAA 2009).

While direct impacts from sea level rise and coastal flooding are important for Miami-Dade County to consider in adaptation planning, there are several other issues of concern to note. One such area of concern is the agricultural sector, which contributes roughly $2.5 billion annually[1] to the national economy, and can be significantly impacted by weather and climate change. Changes in precipitation and temperature patterns, as well as soil salinity from salt water intrusion, can change the type and range of plants and crops that can be grown. Additionally, heavy rain events and freezes can lead to extensive crop damage. For example, the January 2010 extended cold weather and freeze led to over $280 million in agricultural losses.[2] These stresses, combined with increasing pressure from development, could pose significant challenges to the County's agricultural future.

50.3 Miami-Dade County Today – Preparing for Climate Change

With over two decades of environmental leadership experience, Miami-Dade County is a national leader in integrating environmental concerns into daily operations. Recognizing the increased urgency for dealing with climate change, the County created a formal Climate Change Advisory Task Force (CCATF) that has been instrumental in providing guidance and recommendations on both adaptation and mitigation issues to the Miami-Dade Board of County Commissioners. It includes individuals who were key players in the original Urban CO_2 Reduction Plan or had participated in ad hoc task forces, as well as other individuals who were identified to represent key sectors of the community such as non-profit organizations, universities, building and architecture firms, national parks representatives, regional and state planning agencies, private sector business, and community residents. Six committees were formed to focus on key areas of concern; each chaired by a member of the Task Force and comprised of participants from the Task Force and the public. The Task Force has been a vehicle for community engagement in the County's climate change efforts, ensuring that voices from important community sectors are integrated into long-term adaptation and mitigations strategies. While the Task Force does not have the authority to make decisions, it does provide critical input and feedback, and helps to facilitate support from the community. To date, 56 recommendations have been forwarded to the Board of County Commissioners and several are already being implemented. To learn more, see: http://www.miamidade.gov/derm/climatechange/taskforce.asp.

[1]Estimated economic impact, for Miami-Dade County, according to the University of Florida Institute of Food and Agricultural Sciences (UF/IFAS).

[2]Estimated 2009–2010 agricultural losses for Miami-Dade County provided by Charles LaPradd (Miami-Dade Agricultural Manager).

Furthermore, Miami-Dade County decided to engage in a sustainability planning process, to integrate environmental, social and economic concerns into one comprehensive sustainability plan called ‘GreenPrint – Our Design for a Sustainable Future’ (GreenPrint). Development of GreenPrint is based on a Sustainability Planning Toolkit created by the ICLEI in collaboration with New York City. The Plan is being developed to serve as an overarching community-wide sustainability plan to reaffirm, establish and synchronize the County government and community goals, initiatives, and measures. It will integrate with existing County efforts and additional community plans. GreenPrint will not only make County government operations greener, but will also improve the community’s overall sustainability and quality of life.

The planning process and GreenPrint will adhere to the following guiding principles:

- The County will lead by example;
- The concept of sustainability will guide policy and decision-making;
- Metrics and targets will be used to define goals and measure progress;
- The County will collaborate with local municipalities and neighbouring counties to create a sustainability movement among multiple local jurisdictions;
- Partnerships between jurisdictions and between the public and private sector are necessary to achieve sustainability goals;
- Transparency and accountability will guide the County’s sustainability actions;
- Initiatives in the plan will be designed to be aggressive but achievable;
- The County will ensure the benefits of sustainability policies are equitably distributed to all residents;
- The plan will reflect community demographics and the economy and include key sustainability components addressing both County operations and the community as a whole.

Public and institution-wide engagement and support of GreenPrint are crucial for success. To address this, two groups were formed to participate in the process from the beginning. An Interdepartmental Team (I-Team) was created and is comprised of appropriate staff from key County departments. While every County department is charged with defining initiatives to make their operations more sustainable or “green,” the Interdepartmental Team is also responsible for assisting in the development of the plan, as well as coordinating the County’s efforts. This will ensure that the collective objective for all County activities is smart, and sustainable investments are a normal part of doing business. The second group formed is the Mayor’s Sustainability Advisory Board (MAB), which serves as a key stakeholder group for the development and implementation of GreenPrint. The Board represents diverse constituents, which include elected officials, business and real estate leaders, community designers, environmental and advocacy groups, academia, and regional planners. The role of the Board is to provide expertise on county-wide sustainability challenges and offer strategic direction and advice for GreenPrint’s development. Additionally, experts in the field of sustainability and staff from the Miami-Dade County Public Schools provide valuable insight.

To further support these primary programs and the overall climate change mitigation and adaptation efforts, the County is leveraging support and engagement from numerous levels and organizations. For example, efforts to address greenhouse gas emission reductions are being supported by the federal Energy Efficiency and Conservation Block Grant (EECBG) and the Environmental Protection Agency's (EPA) Smart Growth Implementation Assistance. Additional resources are being further explored on a regional basis through the U.S. Department of Transportation's Liveable Communities Program, which is a collaboration between the U.S. Environmental Protection Agency and the U.S. Department of Housing and Urban Development (HUD). In addition, the County has partnered with the National Oceanic and Atmospheric Administration (NOAA)'s Digital Coasts Initiative, to train County department staff on potential climate change impacts and implications to County operations, and to develop a case study about Miami-Dade County, which will serve as an example for other coastal communities. Furthermore, the County is working directly with the U.S. Geological Survey (USGS), to develop an integrated surface-groundwater model to help better understand the interactions between surface and ground water, and the potential effects of sea level rise on these water resources. The ultimate goal is to develop models for the South Florida region that will allow data between the counties and different models to be exchanged. This approach of tackling climate change issues at multiple levels will continue to be a key to the County's success in the future.

50.3.1 Challenges and Lessons Learned

Throughout Miami-Dade County's adaptation and sustainability process, the County has faced numerous challenges and overcome many obstacles. This section explores some of the lessons learned and challenges the County still needs to overcome to address climate preparedness.

- *Extensive breadth of issues*: Climate change is a complex issue with multiple impacts that span all agencies/departments, and all sections of society. This can be an enormous hurdle to overcome and poses difficulty in conveying the need for action.
- S*cience uncertainty and time frame*: One significant obstacle to overcome is determining which climate change projections to utilize for planning from the numerous and varied impact projections that currently exist. The extended time frame of projected impacts (e.g., 2050, 2100), in conjunction with shorter-term decision-making, create a challenging political dichotomy. This is further exacerbated by the reality that some impacts may not be felt until far into the future but require tough decisions to be made today.
- *Scale and complexity of data*: Vast amounts of data need to be gathered and analyzed in order to guide decision making. In addition, systems, programs, and security mechanisms need to be created to store and manage this data to ensure

data accuracy and integrity. Creation of these systems can be a lengthy and resource-intensive process.

- *Competing and immediate needs*: Miami-Dade County provides all basic services to residents in the County. Climate change impacts will affect most of these services but can also be seen as a separate priority which creates competition between existing, more immediate needs and the need to take action now to prepare for future challenges.
- *Current economic and budget constraints*: Communities across the U.S. are currently grappling with how to deliver basic services while facing a severe budget shortfall. Miami-Dade County is no different and is struggling with integrating climate adaptation and preparedness activities into operations, while also dealing with the reality that this is likely to create added burdens on already strained budgets.
- *Land use realities*: Can coastal development really be thwarted? In regards to climate change, it's clear that it should, but how can this become a reality? Making tough land-use decisions will require support from federal, state, regional, and local counterparts, which can be challenging to foster.
- *Turning science in to action*: How does a community translate complicated and often 'difficult-to-understand' issues into action? This, along with effective communication, is the key to moving forward and aggressively addressing and acting on climate change.
- *Effective communication*: The most important stepping stone to climate change policy can often be the most challenging obstacle to overcome. Effective communication is pivotal in dealing with any community-wide issue. This is a challenge when dealing with a diverse population and limited resources.

While the above areas are challenges that Miami-Dade County is or will be facing, there are numerous lessons the County has learned that have been instrumental in creating a culture conducive to adaptation planning. The County is striving to make the most of these lessons learned:

- *Start with and build upon existing successful efforts*: Evaluating and assessing what has already been implemented can provide a good foundation to move forward from and build upon. This can be anything from existing plans or programs, to stakeholders. Miami-Dade County has taken important steps and gained critical knowledge in climate change adaptation through implementation of its existing Stormwater Master Plan (SMP) and Local Mitigation Strategy (LMS), as well as its long history of mitigation efforts.
- *Greenhouse Gas (GHG) emissions reduction efforts must continue in earnest as adaptation proceeds*: Emission reduction efforts should expand and intensify as part of the adaptation process rather than being replaced by it. Miami-Dade County is leveraging existing initiatives and current federal support through the EECBG Program and others previously mentioned, to expand its mitigation efforts.
- *Local governments can effectively lead in climate adaptation efforts*: Progressive and proactive governments are and should continue to lead the way, rather than

waiting for national guidance and efforts. In this regard, local governments have shown time and time again that they can effectively lead the way when it comes to tackling tough issues – ICLEI members are prime examples and Southeast Florida is leading the way with regional collaboration between four major Florida counties (Miami-Dade, Broward, Monroe, and West Palm Beach) in the progressive South Florida Regional Climate Compact.

- *Strategies and plans must be flexible to adapt to new opportunities and overlapping goals*: Flexibility is key to adaptation, as climate change science is constantly evolving. Miami-Dade County will be incorporating new information and data into annual updates of GreenPrint and departments' strategic planning efforts, in order to move forward more effectively and efficiently.
- *Stakeholder involvement from the beginning is important*: Stakeholder involvement is critically important, not only to generate support, but also to keep initiatives on track and provide checks and balances. Miami-Dade County has utilized its Climate Change Advisory Task Force and Mayor's Advisory Board to engage various levels of the community and gain their support.
- *Decision-Makers' commitment and leadership matters*: Decision-makers are obviously key stakeholders. Experience has shown over and over again that without their commitment and leadership, progress and success is highly unlikely. Miami-Dade County has been fortunate to have this support and commitment for many years, as exemplified by its leadership in addressing climate change issues since the early 1990s.

50.4 Conclusion

Miami-Dade County already has gained knowledge and skill in preparing for projected future impacts of climate change due to the County's experience and implementation of its progressive programs. As has been discussed, many of the existing or ongoing activities at various levels overlap and feed into each other quite extensively. This has been a source of strength for the County, particularly as it pertains to sustainability and adaptation planning, and the development of policy recommendations for local decision-makers. This multi-faceted approach has been, and will continue to be, a decisive key element in the County's efforts to become a climate resilient community of the future.

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Chapter 51
Quito's Climate Change Strategy: A Response to Climate Change in the Metropolitan District of Quito, Ecuador

Carolina Zambrano-Barragán, Othon Zevallos, Marcos Villacís, and Diego Enríquez

Abstract Climate change is one of the most challenging social, environmental and economic issues Ecuador and its capital, the Metropolitan District of Quito, are facing. It is estimated that in the last 100 years, the average temperature in Quito increased by 1.2–1.4°C, causing significant change in weather patterns and directly and indirectly impacting ecosystems, infrastructure, water availability, human health, food security and hydroelectric generation, among others. In response to current and projected impacts, the municipality of Quito adopted Quito's Climate Change Strategy (QCCS) in 2009. In coordination with key stakeholders, including the academia, the municipality is currently implementing a series of adaptation and mitigation measures in key sectors. Actions fall under four strategic axes: (1) information generation and management; (2) use of clean technologies and good practices for adaptation and mitigation; (3) communication, education and citizen participation; and (4) institutional strengthening and capacity-building. Given the importance of water resources for the city and its surroundings, measures to face climate change in the water provision and risk management sectors are at the core of the strategy. Quito is one of the few Latin American cities that have a local policy instrument such as the Climate Change Strategy, which together with the use of the city's ecological footprint as a planning tool, put the city at a vanguard in local responses to climate change.

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51.1 Background

In the last decade, the Metropolitan District of Quito (MDQ) has been affected by floods, droughts and landslides that have arisen from the confluence of natural climate variability and climate change. It is estimated that between 1891 and 1999, the average temperature increased by 1.2–1.4°C (Villacís 2008; MMDQ2 2009), causing significant change in weather patterns and directly and indirectly impacting fragile ecosystems (such as paramos and tropical forests), as well as water availability, human health, food security and hydroelectric generation, among others.

The Metropolitan District of Quito (MDQ) is the capital of Ecuador, located in Northwestern South America. The urban area of Quito holds 1.6 million inhabitants, and the District, with a total of 2.1 million inhabitants, presents a population density of 118 people per hectare, and 43.50% of the population living under the national poverty line (MMDQ1 2009). Most of the urban area is located in a valley next to the Pichincha volcano (part of the Andes Mountains), forming a strip of 25 km long by 8 km wide approximately. The city itself is located at 2,580 m asl., while the whole District presents an elevation range between 500 and 4,500 m asl. Like Ecuador, the District of Quito has a high level of biodiversity, with 62% of its total area being covered with natural ecosystems (with low intervention) (see Fig. 51.1). The main economic activities of the population are: trade, manufacturing, construction and governmental functions (INEC 2002). Together with its natural patrimony, Quito is recognized worldwide for its historic center and its cultural heritage, being declared the First World Cultural Heritage.

The extent of its current and future impacts makes climate change one of the most challenging social, environmental and economic issues Ecuador and Quito are facing, and calls for a strong and coordinated policy response at all levels of State. As presented in this article, in recognition of this need, the municipality of the Metropolitan District of Quito (MMDQ) is currently implementing adaptation measures under Quito's Climate Change Strategy, where the water resources sector is a key focus of work.

51.1.1 Quito's Climate: Past, Present and Future

The intra-annual precipitation in Ecuador is complex and is mainly controlled by both the marine seasonal displacement (from 10°N in July to 30°S in December) of ITCZ (Inter Tropical Convergence zone) and the SACZ (South Atlantic Convergence Zone) development from September to March (Hastenrath 1997). As a result, in the Metropolitan District of Quito, located in the inter-Andean valley, a bimodal

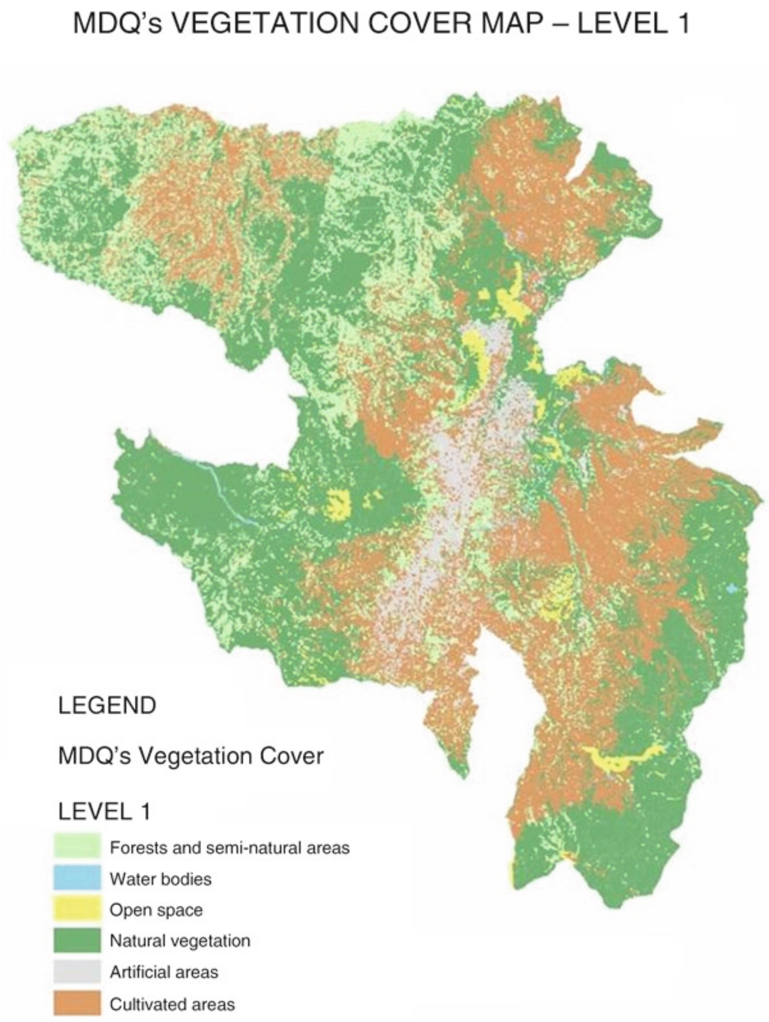

Fig. 51.1 Environment Secretariat – MMDQ (2010) Memoria Técnica Mapa de Cobertura Vegetal del Distrito Metropolitano de Quito, Ecuador. Scale 1:25,000

precipitation distribution with two precipitation maxima March–April and October–December, with a mean annual precipitation of 1,204 mm, is observed. Temperature shows an absence of a seasonal cycle at the MDQ and the annual mean is 13.4°C. The daily cycle varies intensively, reaching a historical maximum of 29.9°C during the day and a historical minimum of 1.5°C during the night (Pourrut 1995).

Historical observations for the twentieth century show a weak decreasing trend in precipitation of 8 mm per decade (Pourrut 1995), which is coherent with the

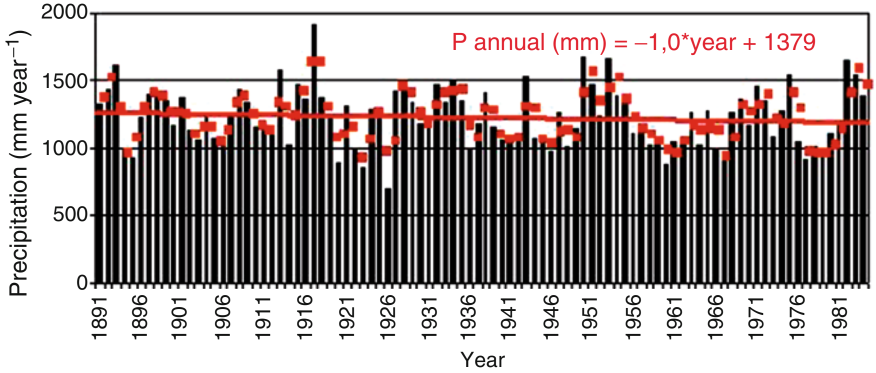

Fig. 51.2 Precipitation trend for the period 1891–1989 (*red line*) for the EPN Quito Observatory station

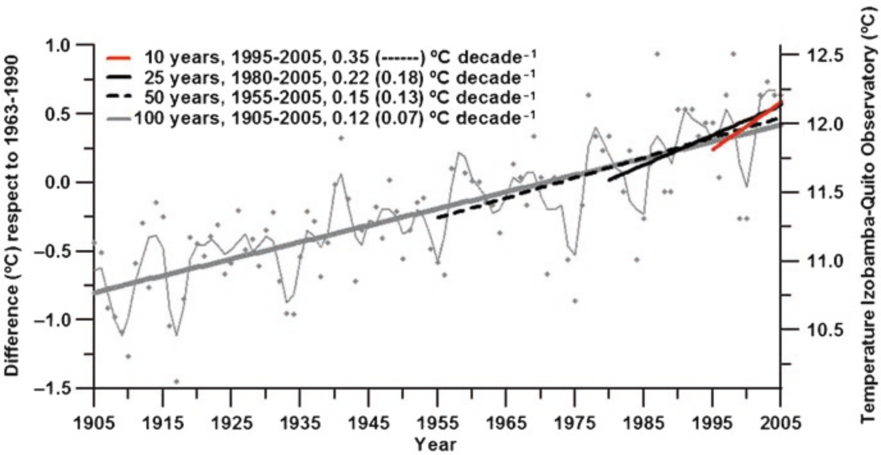

Fig. 51.3 Temperature trends for the last 100 (*gray line*), 50 (*discontinuous black line*), 25 (*continuous black line*) and 10 (*red line*) years for INAMHI's Izobamba station (reconstructed since 1963–1905 with the data from the EPN Quito Observatory station). *Values in parenthesis* represent the global trends (Trenberth et al. 2007) (Modified from Villacís 2008)

regional behavior observed in the last 40 years (Martínez et al. 2011; Fig. 51.2). In the meantime, changes in the mean annual temperature are of the same order of magnitude that the changes observed at the global scale established by Trenberth et al. (2007), with values for Quito showing an increase of 0.12°C, 0.15°C and 0.22°C per decade during the last 100, 50 and 25 years respectively (Villacís 2008; Fig. 51.3). A total increase of 1.2°C has been observed for the last 100 years. The urban heat island effect for the last 30 years was corrected by other data series located in the city's periphery.

With regards to the future, under the A2 scenario of the IPCC an increase of 3.5°C for the next 100 years at the altitude (2,800 m asl) and latitude of the city of Quito is expected. Studies show that over the Equator, changes in temperature are going to be more important at higher altitudes (Bradley et al. 2006). Even though other research concludes that trends in temperature at different altitudes on the tropics are overestimated by some of the climate models (Douglass et al. 2007) for the period between 1979 and 1999, some of them have shown good performance. Consequently, uncertainty attributed to the models themselves can be reduced significantly by choosing the climate models that work better for tropical regions when developing climate change impact studies for the Metropolitan District of Quito.

51.1.2 Climate Change and Water Resources

The combination of higher temperatures and less precipitation can increase water stress in the region and in the MDQ specifically, exacerbating a problem that already exists due to population growth. Under the A2 climate scenario, we also expect a negative impact (reduction of capacity to stock water) over the endemic ecosystem (Buytaert et al. 2009) known as *paramo*, which supplies water to the MDQ. The contribution of water from glaciers will be also reduced and it could possibly disappear completely in the future (in 60–140 years depending of the climate change scenario, after Villacís 2008). Even when glacier contribution is not high when compared to the global supply for the city (2–4%), at the local scale (around 4,000 m asl) it can play an important role (35%) as a buffer during the dry season November–February, and in consequence for the state of the *paramo* ecosystem itself (Villacís et al. 2010).

51.2 Quito's Climate Change Strategy: A Policy Response

In response to current and projected impacts of climate change, the municipality of the Metropolitan District of Quito (MMDQ) adopted its local Climate Change Strategy (QCCS) in 2009. Quito is one of the few Latin American cities that have such a policy instrument, which together with the use of the city's ecological footprint as a planning tool, put the city at a vanguard in local responses to climate change.

Quito's Climate Change Strategy (QCSS) is characterized by a strong balance between adaptation and mitigation efforts. It responds to specific local priorities and needs and aims at taking advantage of the technological, financial and political opportunities that the crisis the world is facing offers for change. QCCS falls under Executive Decree 1815, which declared climate change mitigation and adaptation a State Policy (Presidencia de la República 2009).

QCCS has as a main objective: To develop comprehensive policies that guarantee the implementation of adequate, crosscutting and equitable adaptation and mitigation measures to climate change. This will be done by generating appropriate methodologies and management tools for research and the provision of timely information in the framework of broad and ongoing participation of stakeholders and decision-makers in the Metropolitan District of Quito (MMDQ2 2009). In order to achieve this, the QCSS delineates plans and programs under four strategic areas (MMDQ2 2009):

1. The municipality of the MDQ as a whole has access to adequate information to mitigate vulnerability and achieve planned adaptation to climate change in the areas of intervention (knowledge and information generation and management);
2. Use of technologies and good environmental practices to reduce emissions, capture GHG, and improve adaptation to climate change (implementation of specific plans and measures);
3. Communication, Education and Citizen Participation regarding Climate Change;
4. Strengthening the institutional framework and capacities of the MDQ, led by the municipality of Quito.

Strong intra and interinstitutional articulation is the basis for the implementation of the QCCS. Coordinated action, supported by a connection to science and local knowledge, are at the core of the MDQ's effective preparation to face climate change. Articulation with institutions and with science also allows for the avoidance of duplicating efforts and the channeling of the financial and technical resources at the scale required. At the institutional level, two mechanisms are being developed to guarantee such a connection: Quito's Panel on Climate Change – QCCP (a scientific and expert committee to advise the municipality on climate change actions) and the Metropolitan Climate Change Committee, which will include representatives of the main local institutions (see Fig. 51.4).

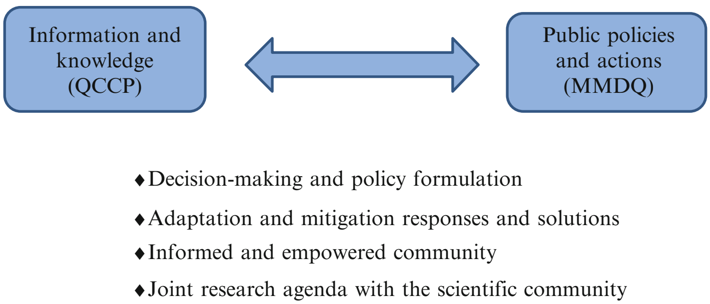

Fig. 51.4 Mechanisms under development to facilitate a connection between science and policy-making: **Quito's Panel on Climate Change** – QCCP (a scientific and expert committee to advise the municipality on climate change actions) and the **Metropolitan Climate Change Committee** (which will include representatives of the main local institutions)

51.2.1 QCCS: Adaptation Actions

Adaptation actions are related to all of the QCCS's strategic areas and focus on five sectors: (1) ecosystems and biodiversity; (2) drinking water provision; (3) health; (4) infrastructure and productive systems, including hydroelectric power; and (5) risk management. The main adaptation initiatives that are being undertaken by the MMDQ are presented below and are part of the Climate Change Action Plan, an implementation plan for the QCCS that is expected to be finished in 2010 (Fig. 51.5 and Table 51.1).

Among adaptation initiatives, the project Quito's Youth and Climate Change provides a good example of participatory and political action to reduce social and environmental vulnerability to climate change in urban areas.

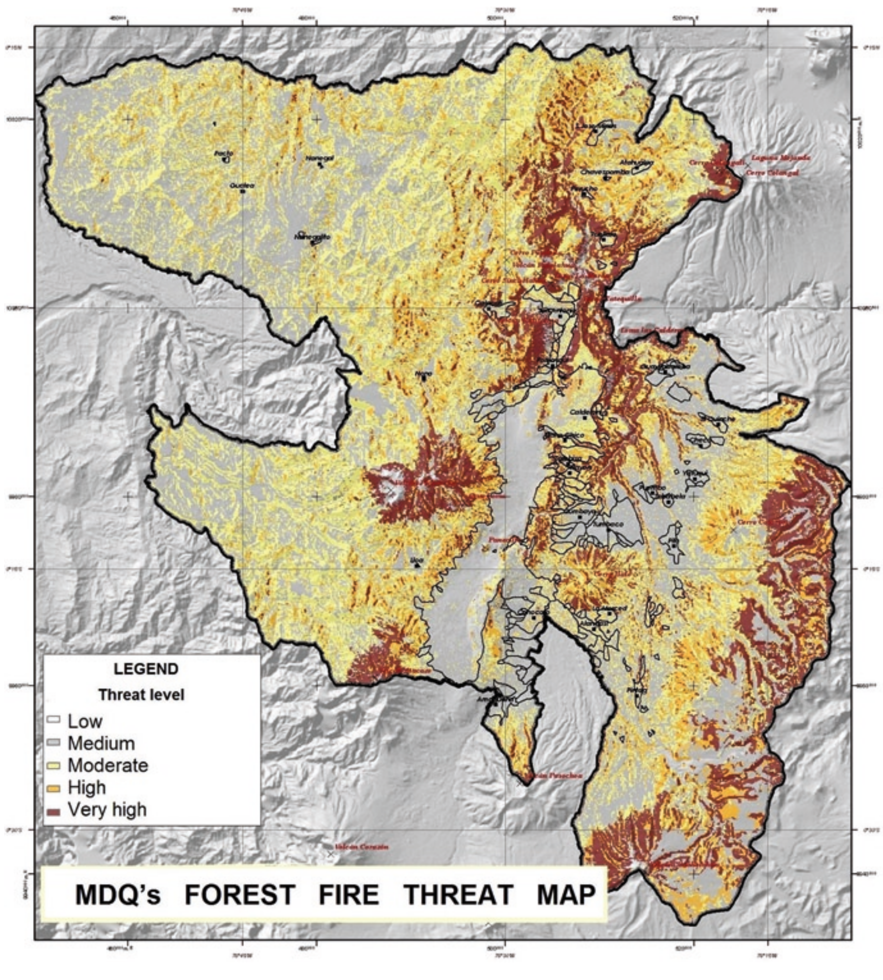

Fig. 51.5 MDQ's Forest Fires Threat Map. Environment Secretariat – MMDQ (2010)

Table 51.1 Quito's Climate Change Strategy: adaptation actions under the four strategic axe

	Implemented/under implementation	Planned for 2010
Access to adequate information	Vegetation map; socio-demographic and poverty analyses; incidence of climate events and forest fires; local GHG inventory; WEAP watershed modeling; glacier monitoring	Vulnerability analyses in all sectors; Land use and land use change analysis; Climate change information system that includes a virtual platform on forest fires' risk management (see Fig. 51.4)
Social participation	Quito's Youth and climate change program; joint research agenda with universities; social forestry initiatives; inclusive informal recycling program	
Plans and measures	Water Master Plan; Fire Plan; Contingency Plan; relocation of families living in risk-prone areas; climate change in land use planning; slope protection; reforestation and ecosystem restoration plan; integrated watershed management	Local protected area subsystem that includes adaptation criteria; analysis of REDD+ as a potential adaptation mechanism; campaigns on efficient water and energy use
Institutional strengthening	Quito's Panel on Climate Change (scientific advisory); Metropolitan Climate Change Committee	Climate Change Action Plan

51.2.2 Quito's Youth and Climate Change

Citizen involvement and the participation of key stakeholders are at the core of the implementation of QCCS. As part of the adaptation actions and with support of the World Bank, the MDMQ is currently implementing the project Quito's Youth Action on Climate Change. This project aims at strengthening local youth's action on climate change by implementing capacity-building workshops in risk-prone marginalized neighborhoods (see Fig. 51.6), strengthening the political agenda of youth movements and funding adaptation and risk management initiatives.

So far, the implementation of the project has been successful. Around a thousand students have been trained and are expected to have a multiplying effect by facilitating subsequent workshops. Simultaneously, the municipality and its partners have launched two calls for adaptation and risk management project proposals. Selected projects will finish implementation in November 2010.

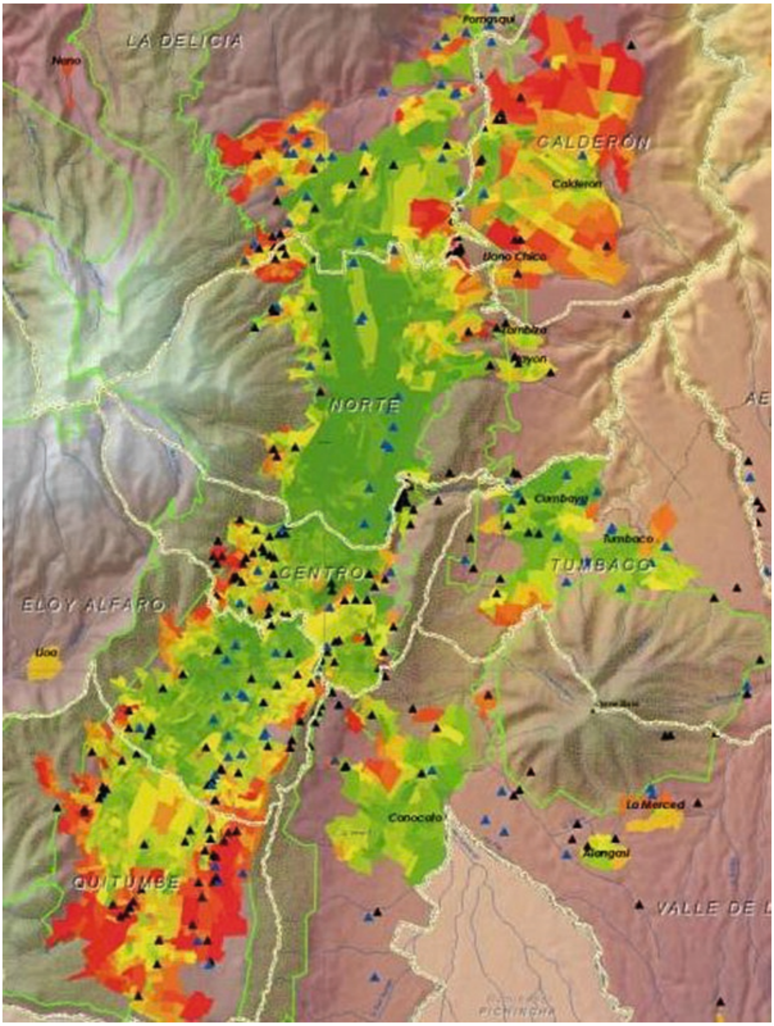

Fig. 51.6 Neighborhood prioritization map: correlation between poverty, floods and landslides (*Source*: Environment Secretariat 2010, Modified from UASB 2009)

51.2.3 Adaptation to Climate Change in Quito: Water Supply and Sanitation Sector

Together with population growth, climate change represents a special challenge for the provision of drinking water and sanitation services to the city of Quito. In response to this, the municipality and the Water Supply and Sanitation Company have designed and implemented strategies, plans and programs to meet their objective of guaranteeing high-quality services for the citizens. Such water supply strategies

Table 51.2 Quito's Climate Change Strategy: adaptation actions in the water resources sector

Axis	Strategic objective	Adaption strategy	Situation
1. The Quito Municipally gets attenuation of vulnerability and planned adaption to Climate change	Research and information	Research in glaciers and paramos	Ongoing
		Water and Sanitation Master Plan 2010–2040	Ongoing
		Wastewater control plan and residual treatment plant for Quito	Ongoing
	Risk management and climatic events	Mountainside management program	Ongoing
		Urban runoff management program	Next
2. Use of Technology and good environmental practices	Mitigation and adaptation	Unaccounted or water losses reduction program (inside or Water Supply Company responsibility)	Ongoing
		Water use reduction program (inside home – citizen behavior)	Ongoing
		Water Protection Financial Fund – FONAG	Ongoing
		Watershed conservation and management program	Starting
		Eco-neighborhoods. Domestic or wastewater separation in homes.	Next

contribute to the city's adaptation to climate change and follow under Quito's Climate Change Strategy (Table 51.2).

Several initiatives involve no-regret adaptation options to climate change and contribute to the creation of a new culture of water use.

51.2.4 Ongoing Actions

51.2.4.1 Water and Sanitation Master Plan (2010–2040)

The Water and Sanitation Master Plan is currently being updated and involves strategic short, medium and long-term planning that considers win-win adaptation measures to face climate change. This process includes two main elements:

- An increase in the average demand for water to 10,300 l/s, considering greater coverage of services, loss reduction and lower consumption.

- A strategy to cope with the increasing demand and the effects of climate change that includes: (1) the advancement of the first stage of the "Rios Orientales project" which will bring 1,364 l/s, with an investment of US$110 million, and (2) the investment of US$190 million to improve the storm drainage system.

51.2.4.2 The Hillside Management Program

Since 1997, the Company has been implementing the Hillside Management Program, which aims at ensuring the integrated management of the slopes that surround Quito, minimizing the threats they pose on the city. So far, an investment of approximately US$40 million has been made to mitigate and reduce risks on the slopes of northern and central Quito.

51.2.4.3 Control and Reduction of Unaccounted Water Plan

The control and reduction of unaccounted water program (ANC) began in 2007. It contemplates some key elements: a hydraulic planning approach; the installation of macro and micro meters; research on the causes of water losses and its control; and, the implementation of the Telemetry and Control System. Through the implementation of this plan, the Water Company estimates that the rate of ANC will decrease by 10% in parishes and 3% in the city.

51.2.4.4 The Integral Plan for Reduction of Water Consumption

This Plan aims at reducing inadequate consumption of drinking water in the area of DMQ, and obtaining an average consumption of around 21 m^3 per connection per month. The project will be implemented in three stages:

- Baseline development considering domestic causes of high consumption and potential reduction strategies;
- Design of consumption reduction strategies;
- Implementation of the Plan.

51.2.4.5 Fund for the Protection of Water – FONAG

FONAG is an investment fund for watershed conservation that operates through a trust since January 2000. The Company contributes to this fund with the 1.5% of the amount of its billing. At the moment, the FONAG holds US$6.6 million and promotes several programs and projects related to reforestation in watersheds, education and environmental monitoring.

51.2.4.6 Climate Change Research

In addition to the plans and programs presented, the municipality and the Company are currently undertaking research on climate change and water supply. This is done jointly with the French Institut de Recherche pour le Développement (IRD) and the Regional Project for Adaptation to Climate Change in the Andes (PRAA), lead by the national Ministry of Environment. The research is related to the impacts of climate change on the retreat of glaciers and the role of "Paramos", highland ecosystems, in water supplies for Quito.

51.3 Future Proposals

51.3.1 Management of Stormwater Runoff Program

The Master Plan studies are considering several alternatives for managing urban stormwater runoff. This involves the hydraulic modeling of sewage networks considering a segmentation of the city depending on the amount of precipitation and characteristics of the urban watershed. This work will optimize the drainage system and will allow its active management. As a complement to these actions, the construction of artificial depressions that will contribute to minimize the flooding is planned. It is also intended to encourage the construction of gardens, communal green areas and even incorporate modern concepts in buildings like the "green roofs". The municipality is also working on a local law that will regulate urban water management.

51.3.2 Eco-Neighborhoods

The Metropolitan municipality is planning to promote the construction of Eco-neighborhoods, which are new buildings that intend to incorporate innovative concepts in water management, energy and solid waste. These new buildings will include systems for the separation of wastewater, the use of rainwater and the reuse of grey water.

51.4 Conclusions and Recommendations

The important steps that the Metropolitan District of Quito has taken provide strategic bases for the management of climate change at the local level. Their success depends on the sustained involvement of the civil society and the progressive consolidation of concrete actions on the ground. In order to manage and adapt to the current and future impacts of climate change, some key elements should be considered in any local climate change strategy:

- Adaptation and the reduction of vulnerability demand significant investment of financial and technical resources, not only for infrastructure, but also for capacity-building in public institutions and awareness-rising. International cooperation and the creation of regional platforms for information and experience exchange are crucial. The work of ICLEI and other international networks should increase its focus on developing country cities and North–South, South–South and triangular cooperation and technology transfer.
- The creation of specific mechanisms to channel financial resources from national to local governments is essential for the appropriate implementation of adaptation actions.
- The successful implementation of local climate change adaptation measures calls for intra and inter-institutional articulation. The creation of climate change city committees, such as the one Quito is creating, can facilitate such coordination. In this context, the consideration of climate change as a crosscutting element of land use and urban planning should be a key area of work.
- The current implementation of non-regret adaptation strategies by the municipality and its institutions must be complemented by specific climate adaptation actions that may only present medium and long-term benefits. In this context, a strong connection between research institutions, key stakeholders and the municipality needs to be maintained. The work of Quito's Climate Change Panel may prove to be crucial for the development of a joint research agenda based on the city's research and information needs.
- In terms of information, cities like Quito need to develop a dynamical data base of adaptation and mitigation indicators, as well as of the impacts of climate change in the different sectors. This allows for the continuous improvement and adaptation of the QCCS and its related policies and programs.
- The municipality of Quito views adaptation and mitigation as complementary. As such, the implementation of mitigation actions that have considerable adaptation benefits should be maximized. One example is the potential conservation of forests through mechanisms like REDD (given that they are designed to maximize biodiversity and social benefits) and the promotion of the resistance and resilience of its associated ecosystem services and livelihoods.
- The interaction with the private sector can be improved, so that resources invested for adaptation and mitigation are optimized.
- Finally, by providing examples of adaptation and mitigation actions with measurable, short- and medium-term impacts, cities like Quito can lay the foundation for national, regional and international policy. Urban and peri-urban areas – that often rely on rural ecosystem services from within and outside the District, such as water – offer great opportunity to test models for the design of national programs, as well as to strengthen synergies between urban and rural stakeholders. A successful and effective implementation of such measures could promote the

creation and consolidation of climate change policies at the subnational and national levels, by demonstrating political, social and economic feasibility.

There are two important initiatives Quito is implementing that could maximize such a multiplying effect in Ecuador and the region: the Manual for Local Climate Change Management and the work of the Ecuadorian Local Environmental Authorities' Network. The first one, a joint effort with UN Habitat, will provide a basic tool for other municipalities in Ecuador to develop local strategies to tackle climate change based on Quito's experience. The second one, which will have a focus on climate change, aims at, among others: standardizing tools and methodologies (vulnerability analysis, GHG inventories, CC Strategies, etc.), creating an experience-sharing platform and promoting the development of joint adaptation activities. Through this work, the municipality of the Metropolitan District of Quito expects to contribute positively to the resistance and resilience of other cities, its citizen and its ecosystems in the region.

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Chapter 52
Climate Change Implications for Dhaka City: A Need for Immediate Measures to Reduce Vulnerability

Golam Rabbani, A. Atiq Rahman, and Nazria Islam

Abstract Dhaka, the capital and only megacity of Bangladesh, is exposed to multiple types of climate- induced hazards including variations in temperature, excessive and erratic rainfall, water logging, flooding, cyclones, and heat and cold waves. These hazards negatively affect city life and livelihoods nearly every year and may worsen as they become coupled with non-climatic factors such as population density, poverty, rural-urban migration, illiteracy, unplanned urbanization and lack of public utilities and services. Immediate measures addressing climate induced vulnerabilities are necessary to the long-term sustainability of Dhaka.

Keywords Climate change • Flooding • Population • Poverty • Vulnerability

52.1 Background

Dhaka is located in central Bangladesh, surrounded by the river Buriganga to the south, Turag to the west, Balu to the east, and the Tongi canal to the north (see Fig. 52.1). The city has a tropical monsoon climate with an annual average temperature of 25°C (77°F) and an average annual rainfall of 2,000 mm (Banglapedia: National Encyclopaedia of Bangladesh 2003). The area of Dhaka city has four administrative boundaries defined by different governmental agencies, including Dhaka City Corporation (DCC), Dhaka Metropolitan Police (DMP) and the Capital Development Authority or Rajdhani Unnayan Kotripakhkha (RAJUK) (see Fig. 52.2). While the DCC covers 276 km^2, the larger Dhaka metropolitan area (DMA) covers 360 km^2. Two distinct areas of the city are further defined by RAJUK and include

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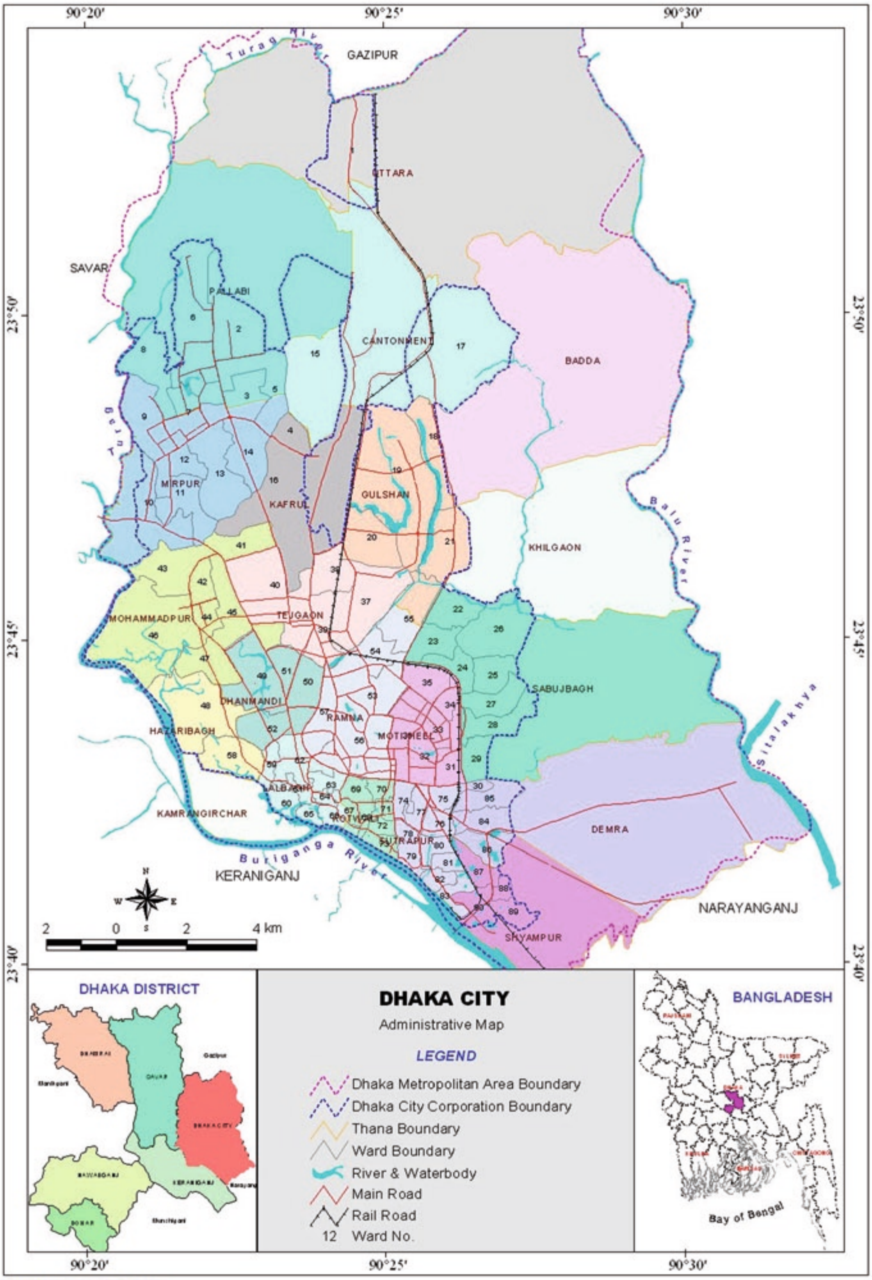

Fig. 52.1 Map of the Dhaka City – showing the administrative boundary and surrounding rivers

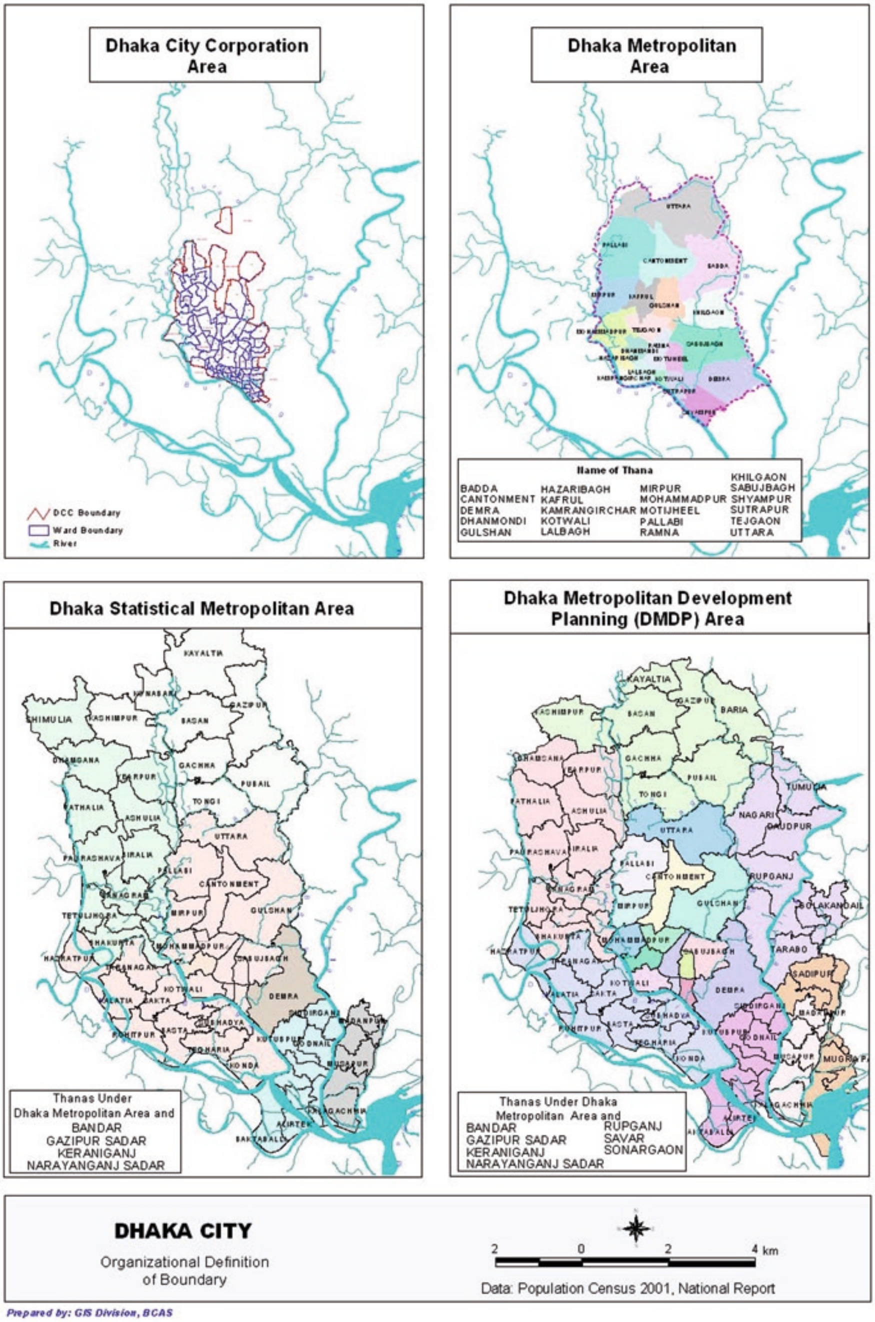

Fig. 52.2 The Area of Dhaka City – organizational definition of the boundary

the Dhaka Statistical Metropolitan Area (DSMA) encompassing 1,353 km^2 (522 $mile^2$) and the Dhaka Metropolitan Development Plan covering 1,530 km^2 (BBS 2001). The last administrative boundary was set by RAJUK for long-term (1995–2015) strategy for the development of the greater Dhaka considering the growth of population, economic development, shelter and housing, social facilities and open space, transport, flood control and drainage and utility services.

52.2 Policy and Institutional Arrangement

Dhaka City is administered by the government of Bangladesh through a number of plans and policies developed by its ministries, departments and agencies. Some of the key policies and plans include: the Dhaka Land Management Project 1994 produced by DCC, the Dhaka Metropolitan Development Plan, 1997, produced by RAJUK; the Detailed Area Plan, 2004 produced by RAJUK; the Dhaka Urban Transport Project (DUTP) produced by Dhaka Transport Coordinator Board (DTCB); and the Master Plan for Solid Waste Management in Dhaka City, 2005 produced by DCC.

With a mandate to provide a number of services including the management of solid waste and surface drainage systems, street lighting, traffic control, water supply, public health and informal settlements, the DCC is the key agency administering the city. Additional agencies include RAJUK, Dhaka Water Supply and Sewerage Authority (DWASA), Titas Gas Limited (TGL), Bangladesh Telephone and Telegraph Board (BTTB), Dhaka Electric Supply Company (DESCO), Department of Environment (DoE), Bangladesh Meteorological Department (BMD), Bangladesh Road Transport Authority (BRTA), Bangladesh Inland Water Transport Authority (BIWTA) and Dhaka Metropolitan Police (DMP), each of which have specific mandates for their services to Dhaka city dwellers.

52.3 Climate Induced Hazards: Sensitivity and Vulnerability

Temperature variations: In Bangladesh, the temperature during monsoon season is projected to increase by 0.7°C and by 1.3°C in winter (World Bank 2000). These recent estimates are reflected in temperature trends within Dhaka. While the city has experienced a slight increase in temperature (March–November) over the last 30 years (see Fig. 52.3 below) (author's analysis) this average has sharply increased during the last 5 years, at a rate of 0.11°C, denoting higher rate of statistical strength (see Fig. 52.4 below).

Climate induced heat and cold waves pose additional challenges for city dwellers in Dhaka. Children and the elderly are particularly vulnerable to these temperature fluctuations. These events have been observed frequently in recent years. Towards

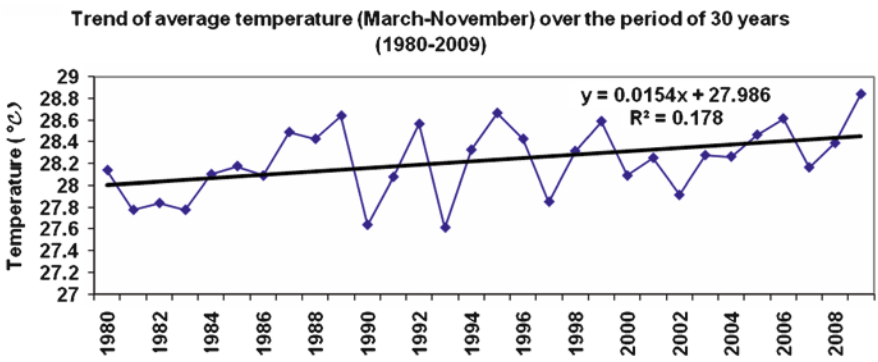

Fig. 52.3 Trend of average temperature (March–November) in last 30 years (1980–2009)

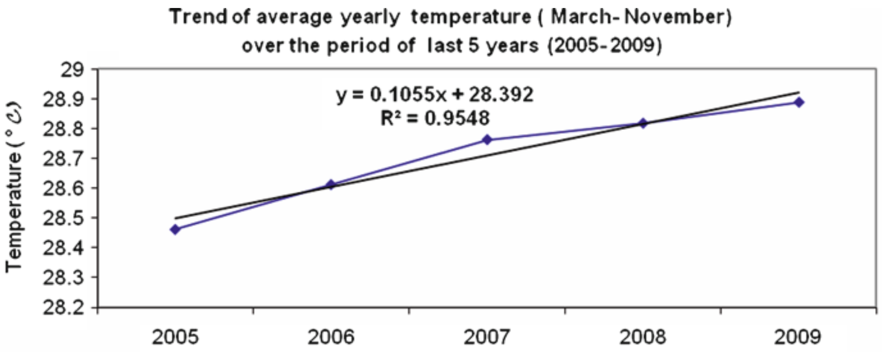

Fig. 52.4 Trend of average yearly temperature (March–November) over the last 5 years (2005–2009)

the end of April 2009, Bangladesh faced a severe heat wave. Throughout the end of December 2009 and the first weeks of 2010, it was also hit by a cold wave.[1]

Heat waves and cold waves have a damaging effect on the human body. Heat stroke, for example, affects not only health, but economic productivity at the individual level, particularly in poor income groups who are day labourers. The burden of costly health treatment in city area and the loss of productivity due to illnesses would push these poorer groups into greater poverty and vulnerability.

Variations to rainfall: A World Bank study (2000) shows an increase of annual precipitation in Bangladesh. An estimation of yearly rainfall from 1978 to 2008 reflects an average rise of about 4 mm per annum in the city. The recent estimate

[1] According to an April edition of the Daily Star (2009) Dhaka suffered a 10 day heat wave accompanied by severe scarcity of safe water, shortage of gas supply, infestation of mosquitoes and the incidences of diarrhoea. The heat wave struck a 14-year record high with temperatures of 38.7°C.

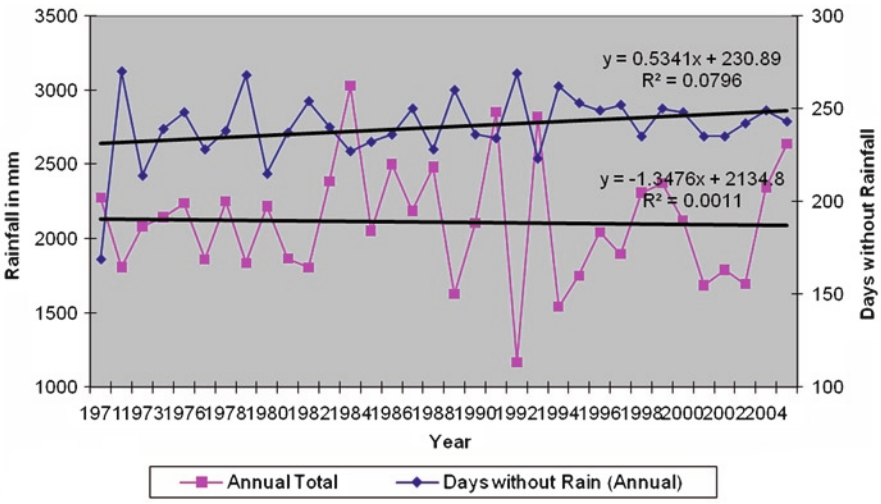

Fig. 52.5 Trend of rainfall and days without rainfall in Dhaka over the period of 1971–2004

demonstrates that over a long-term trajectory overall rainfall does not change drastically, the trend in seasonal rainfall does (Alam and Rabbani 2007). While there is no significant change in the annual average rainfall, the number of days without rainfall is increasing (Alam and Rabbani 2007) (see Fig. 52.5). Observations also suggest that seasonal rainfall during the monsoon (June–August) and winter (December–February) in Dhaka is decreasing during these periods, while sporadic heavy rainfall is becoming more frequent.

Flooding and water logging: In the last half of the twentieth century, Dhaka has faced flooding at least once every 5 years due to the overflow of its surrounding rivers. Of these, the 1988, 1998 and 2004 floods have been the most devastating. In 1988, nearly 85% of the city was inundated. In 1998 and 2004, the eastern part of the city was severely affected while the western half was protected by an embankment along the Buriganga river from Gabtoli to Sadarghat (Alam and Rabbani 2007). Excessive rainfall is also a serious problem in many parts of the city, which can become inundated for several days due to drainage congestion and inadequate pumping facilities.

Cyclone and storm surges: Cyclones and storm surges are another climate induced threat for Dhaka. Although the city is located at the centre of the country, it remains vulnerable to cyclone events. Cyclonic wind, coupled with continuous rainfall, is particularly problematic in low-lying parts of the city, where water logging occurs due to inadequate infrastructure. Risks and vulnerabilities associated with storm surges will increase in the face of the rises in sea level predicted by various institutions. While the World Bank has predicted a 30–50 cm rise in sea levels between 2030 and 2050 (2000) the Intergovernmental Panel on Climate Change (IPCC) places the range between 18 and 59 cm within the twenty-first century (IPCC 2007). Another recent report predicts sea level rise as much as 7 m in case of total melting of the Greenland Ice sheet (ACECRC 2008). With an elevation of 2–13 m above sea level, each projection places Dhaka high on the list of cities threatened by sea level rise (Huq and Alam 2002).

52.4 Non-climatic Factors: What Makes Dhaka City More Vulnerable to Climate Change?

Population: Bangladesh is the most densely populated country in the world and the rapid growth of its population, combined with strong trends of rural-urban migration, places additional pressure on Dhaka City management authorities to meet the challenging demand of providing adequate utility and other services to city dwellers, especially those in slum areas. According to the Bangladesh Bureau of Statistics (BBS), the population of Dhaka metropolitan region and the DCC are approximately 9.9 million and 5.3 million respectively (BBS 2001). The population density of the DCC area is 19, 286/km^2, which is more than double the mega city average of 7,918/km^2 (GoB and UNEP RRCAP 2005). With over 20 million people, the UN estimates that Dhaka will shift from its rank from the world's ninth largest city (2000) to second in terms of total population by 2015 (United Nation Population Division 2001). Table 52.1 below illustrates that since 2001, Dhaka's population density has doubled from 1951 figures, and is projected to triple by 2015.

Poverty and poor living standards: Dhaka's dense population is largely poor, with approximately 50% of Dhaka City earning less than US$2 per day (Islam 1998). Most of the population lives in slums and squatter dwellings frequently exposed to flooding and water logging and without access to safe water and sanitation services.

Rural-urban migration: Millions of people from the coastal region of Bangladesh are under threat from climate change and climate variability. Many have already been displaced from the coastal zone due to the increasing erosion of river banks, cyclone and storm surges, as well as a lack of livelihood opportunities. The predicted

Table 52.1 Trend of population growth and density of Dhaka Megacity (1951–2015) (Source: DCC 2004; Siddiqui et al. 2004)

Year	Area (km^2)	Population (million)	% Increase of population over the preceding year	Density (/km^2)
1951	85.45	0.4	–	4813.09
1961	124.45	0.7	74.76	5775.54
1974	335.79	2.0	187.76	6159.66
1981	509.62	3.4	66.32	6750.41
1991	1352.82	6.8	98.95	5059.16
2001	1352.82	10.7	56.51	7918.43
2010	1352.82	14.0	30.84	10,348
2015	1352.82	16.0	14.28	11,827

sea level rise and higher intensity of cyclone events may cause increases in both internal and external migration, placing further stress on poverty-inflicted areas within Dhaka's urban slums.[2]

Access to services and utilities: Many city dwellers lack access to safe water supply and sanitation, electricity, gas, and solid waste management. Existing services are insufficient for city residents, and the capacity to deliver services to city residents, particularly electricity and water supplies, is affected by climate-related impacts. For example, while DWASA can usually meet around 70% of water demand in the city, the supply is stretched in the face of increased demand in pre-monsoon periods.

52.5 Synthesis: Climate Change Vulnerabilities for Dhaka City

While Dhaka City is a fast growing megacity, its growth has its limitations. These limitations are partly related to the inability of the current population to cope with the intensity and magnitude of existing climate impacts. The combined risks associated with heightened temperatures, irregular patterns and intensity of rainfall and storm surges illustrate that Dhaka's climate-related risks are closely related to issues such as public health, service delivery and livelihoods.

It has been observed that the seasonal rainfall in monsoon and winter in Dhaka City shows an overall trend of decreasing, while instances of erratic and excessive rainfall will increase, causing water logging. This will obstruct the smooth administration in the provision of utility services such as water and energy supply, road transport system, and sewerage and solid waste management.[3]

Sharp increases in average temperatures will generate a higher demand in Dhaka for cooling systems in homes, business houses and transport facilities, which may cause disruptions by affecting the ability of the city to provide adequate energy and water supplies.

Higher temperatures and instances of extreme rainfall will affect public health, as rapidly breeding bacteria and viruses will increase incidences of disease. For example, one study has found that the seasonal peak of *E. coli* induced diarrhoea in Bangladesh can be linked to higher temperatures and greater risk of food contamination due to bacterial growth (Rowland 1986). According to International Centre for Diarrhoeal Diseases Research Bangladesh (ICDDRB) incidence of diarrhoea and increased rainfall are heavily related, especially during the latter half of the

[2] According to Local Environment Development and Agricultural Research Society (LEDAR). The aftermath of cyclone Aila in May 2009 caused the submersion of 25,000 houses. 95 families in the Gabura Union under Shyamnaga Upazilla of Satkhira District had to migrate elsewhere, most settling in the nearest urban areas, and to the capital, Dhaka.

[3] The BMD states that 290 mm of rain fell in 6 h in 28 July 2009, reaching a 60 year record for Dhaka. Nine people were killed in damages associated with high winds (Shelter for the poor, 2009)

rainy season (Wagatsuma et al. 2003). For example, incidences of rotavirus diarrhoea increase by 40.2% in Dhaka for each 1°C increase of temperature above 29°C (Hashizume et al. 2008).

Flooding and sea level rise will continue to play increasingly significant roles in Dhaka's vulnerability to the effects of climate change. Heightened temperatures will contribute the melting of Himalayan permafrost, resulting in heavier water flows through the Ganges, Meghna and Brahmaputra river systems into Bangladesh and contributing to additional flooding of the central flood plain where Dhaka is located (Rahman et al. 2007). Rising sea levels will also affect the city in terms of agricultural productivity and risks to other livelihoods and settlement.

52.6 Response of the Government

The Government of Bangladesh is concerned about addressing climate change. The country has developed the National Adaptation Programmes of Action (NAPA) in 2005 (revised in 2009) and the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2009. The government also allocated about US$ 100 million to address climate change. Projects under the Government's Climate Trust Fund (CTF) are in the process of being implemented. Recently, the Multi–Donor Trust Fund (MDTF) has been renamed as the Bangladesh Climate Resilience Fund (BCRF), which is to be processed and disbursed in due course. The total amount under BCRF will be about US$ 110 million. This fund will be utilized to implement the BCCSAP.

52.6.1 Potential Measures: Addressing Climate Change in Dhaka City

The following measures should be taken immediately to address climate change impacts and vulnerability in Dhaka:

- Broad based research to map and identify vulnerable sectors in need of potential adaptation measures;
- A review of DCC, RAJUK and DWASA policies and plans for incorporation of climate change and climate variability issues;
- A review of the Detail Area Plan (2005–2015). The Capital Development Authority or RAJUK may take necessary initiative to review the DAP to make it climate resilient. RAJUK may form a multidisciplinary team to review the DAP and incorporate climate change issues accordingly;
- Construction of flood reservoirs in surrounding river basins to reduce flood risk. For example, it was suggested that the discharge to the Dhaka River System (Buriganga, Turag, Balu, and Shitalakhya) could be increased through controlled

release from the reservoirs during the dry season. This could provide surface water for consumption in some parts of Dhaka;

- Extension of health services to address climate change and climate variability. Effects on health should be monitored regularly and seasonally;
- Both governmental and non-governmental organizations should initiate projects/programs to reduce vulnerabilities and impacts of climate change

52.7 Conclusion

Climate change is the greatest threat of the twenty-first century. In Bangladesh, one of the countries most vulnerable to climate change, impacts are already evident. The extent of damage to Dhaka, a city currently lacking proper response mechanisms, remains uncertain. In Dhaka, the combination of multiple climatic factors such as temperature variation and erratic rainfall with non-climatic factors such as population density and poverty may affect city life adversely. Socio-economic uncertainties of Dhaka's city dwellers, one-third of whom live in slums, are also expected to produce a multiplier effect resulting in an increase in morbidity and mortality for future generations. Responding to these risks and vulnerabilities requires immediate action from city authorities. Although climate change has become a serious concern of government, urban adaptation issues still receive limited attention. Government plans and policies should ensure the wise application of available funds – combined with the efforts of NGOs and research institutions – to address climate change through a holistic approach in both rural and urban contexts.

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Chapter 53
Adaptation in Practise: Durban, South Africa

Andrew Mather, Debra Roberts, and Geoffrey Tooley

Abstract This paper outlines the development of the first municipal adaptation plans for climate change in Durban, South Africa. Particular attention is paid to the storm water and coastal plans developed for the water sector. Key adaptation activities in the main operational departments are highlighted as well as the key challenges and lessons learned during the development of the plans. Three factors were significant in determining the success of the project: (1) the emergence of political and technical champions, (2) the existence of high level technical expertise within the municipality and (3) broad based and appropriate communication with stakeholders.

Keywords Climate change adaptation • Coastal erosion • Durban • Sea level rise • Stormwater flooding

53.1 Introduction

Durban, South Africa, is the largest port and city on the east coast of Africa, with a population of approximately 3.7 million people. Since 2004, eThekwini Municipality (the local government responsible for planning and managing the city of Durban) has been working on the development and implementation of a Municipal Climate

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Protection Programme (MCPP). A recent analysis by Roberts (2010) indicates that in many ways the MCPP is similar to the climate change programmes of other major cities (e.g., London and New York), incorporating both an assessment of local level impacts and the development of locally-focused response strategies. What sets cities like Durban apart, however, is its strong and early focus on climate change adaptation. This is in contrast to many local governments, whose tendency is to prioritise mitigation. A key reason that adaptation has achieved such prominence in Durban is that adaptation or resilience-focused interventions offer the potential for developmentally linked co-benefits that are responsive to a context of poverty and underdevelopment. In contrast, mitigation's focus on carbon is abstract, often poorly understood and raises equity issues about who has caused and is responsible for addressing the problem. Experience in Durban also suggests that as events linked with climatic uncertainty increase (particularly those resulting in rapid onset disasters) political support for climate change adaptation interventions will increase.

53.2 Development of the Adaptation Workstream Within the MCPP

The adaptation work-stream of the MCPP was initiated in 2006 (following the completion of the initial climate change impact analysis) with the development of a Headline Climate Change Adaptation Strategy (HCCAS). The key objectives of the HCCAS were to identify which key municipal sectors would be impacted by incremental climate change and to highlight appropriate and practicable adaptation options. The sectors reviewed included: human health, water and sanitation, solid waste, coastal zones, biodiversity, infrastructure (i.e., electricity and transportation), food security and agriculture, strategic planning, and economic development and disaster risk reduction (Roberts 2010).

It became clear during the preparation of the HCCAS that there were significant differences in the institutional ability of various municipal sectors to respond to climate change. Some sectors (such as water) were already undertaking work that had co-lateral adaptation benefits, and were well positioned to act as future 'climate champions.' Others demonstrated a limited awareness or prioritisation of climate change issues (e.g., economic development) or were prohibited from taking effective action (e.g., disaster management) by structural limitations (Roberts 2010).

While the HCCAS process was useful in engaging municipal sectors in a discussion of climate change impacts and possible responses, it did not ultimately stimulate new adaptation actions. The exception was the biodiversity sector, which (prompted in part by the HCCAS process) began investigating the likely impact of climate change on the city's globally significant biodiversity. The intention was to use this information to improve the design and resilience of the Durban Metropolitan

Open Space System (D'MOSS).[1] The only reason for this variance from the norm was the fact that the department overseeing the development of the HCCAS and the MCPP – the Environmental Planning and Climate Protection Department – (EPCPD) – is also the department responsible for undertaking biodiversity planning in the city (Roberts 2010).

Although no formal analysis of the failure of the HCCAS process was undertaken, past experience suggests a number of factors were probably critical; inter alia, the high-level and generic nature of the strategy, excessive existing workloads, urgent development challenges/pressures that result in issues perceived as less urgent being ignored, the perception of climate change as a distant and unlikely threat, and a shortage of skills and funds. This situation is exacerbated by the implicit (and often explicit) assumption that environmentally related issues such as climate change will be dealt with by the EPCPD, so there is no need to engage with them at any depth (Roberts 2010).

To address these issues, it was decided that a more successful approach would be to embed the adaptation planning process through the development of sector-specific adaptation plans that were fully aligned with existing business plans, development objectives and available funding and skills. Switching to a sector-based approach might be regarded as contrary to the emerging consensus that adaptation planning should be an integrated and cross-sectoral process; however, it became the only practical means by which to begin mainstreaming the process of adaptation planning in a municipal environment dominated by competing and often conflicting sectoral and political interests. Essentially, the goal was to build increased resiliency one adaptation intervention at a time (Roberts 2010).

Two pilot sectors (i.e., health and water) were initially selected to test this more focused approach. Within each sector the adaptation needs of the component line functions were identified. In the water sector, these included water sanitation, coastal, stormwater and catchment management and coastal policy. In the case of the health sector, the component line functions were clinical health, environmental health, communicable disease control and social development (including food security). These two pilot sectors were selected because of their vulnerability to existing climate variability and projected climate change risk,[2] their importance to the city's development agenda, the fact that the EPCPD already had a good working relationship with key individuals within these sectors, and the fact that these two sectors would be affected by similar climatic factors (e.g., the loss of waste water treatment infrastructure during a storm might have impacts on health). The functional relationship between the two sectors was regarded as important since it was considered likely that the best adaptation responses would be those that engaged a broad range of actors and responded to a spectrum of risks and threats (Roberts 2010).

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[1]The municipal wide open space system designed to protect local level biodiversity and the associated ecosystem services it provides.

[2]This draws on the concept of 'total climate risk,' i.e., both current climate risk and the additional future risk that climate change may present (Economics of Climate Adaptation Working Group 2009).

During the process of developing the health and water Municipal Adaptation Plans (MAPs) it became clear that regardless of the level of adaptation achieved in each sector, the need to respond to emergency situations that exceeded the capacity of these sectors would continue to exist. Parry et al. (2009) refer to infrastructure loss and environmental damage that cannot be adapted to as ‘residual damage’ because it is neither economical nor feasible to prevent. In Durban, this residual damage or risk is likely to include the loss of infrastructure, displacement and isolation of individuals and/or communities, increased human injuries and emergency medical cases, multiple different emergencies over a wide geographical area, and disease outbreaks and food shortages (Environmental Resources Management, Southern Africa 2009). Given that the disaster management function will have to deal with these residual impacts, it was determined that this function should be drawn into the pilot project. As a result, then, a MAP was produced for the disaster management sector (Roberts 2010). This paper describes the adaptation plans developed in the stormwater and coastal line functions of the water sector.

53.3 Adaptation in the Stormwater Sector

53.3.1 Background

Potential increases in the intensity of rainfall events for the Durban region could lead to higher runoff and stream flow (due to higher overland flow and reduced infiltration), which in turn could lead to an increase in flooding in flood prone areas. Knoesen et al.’s (2009) modelling suggests a potential increase in flooding as a result of the following:

- an increase in mean annual rainfall of up to 20% by mid century and 30–100% by the end of the century;
- an increase in the number of days with more than 10 mm rain of 10–30% by mid century and 30–100% by the end of the century; and
- a change in flood magnitudes for a 2 year return period over the medium term which could potentially double by the end of the century.

53.3.2 Municipal Adaptation Plans for the Stormwater Sector

It is essential that any approach to developing an adaptation plan for the stormwater sector considers the suite of potential impacts facing a region and identifies activities that will reduce as many of these impacts as possible. Climate change adaptation will impose costs on eThekwini Municipality, but so too would not adapting to the impacts of climate change. The latter costs could be even higher. Given that eThekwini Municipality cannot assume responsibility for (or even ‘enable’) all the adaptation responses required, and given the complexity and range of climate change impacts likely to affect the city (i.e., impacts on ecosystems, markets and livelihoods), the challenge is for the municipality to identify the few plausible interactions that will result in the greatest reduction of climate change risk. It is possible that a large number of potential impacts can be prevented or reduced by implementing a few key activities. A number of key adaptation interventions have been identified for the stormwater sector as shown in Table 53.1. Using a multi criteria approach these were ranked into high, medium and low priorities.

53.4 Adaptation in the Coastal Sector

53.4.1 Background

Climate change will produce sea level rise from glacial melt and thermal expansion of the oceans. This rise in sea levels will differ along each continent’s shoreline, and its impact will vary depending on the steepness of the coastline. Since the coastline of Durban has been subject to coastal erosion over recent years, an understanding of the likely extent of sea level rise (SLR) was urgently required in order to understand the localised impacts that might occur, the infrastructure and assets which would be at risk, and to allow proactive adaptation to these impacts into the future.

The first step was to determine which scenarios of sea level rise need to be considered in the city’s planning. The current rate of sea level rise along the Durban coastline is 2.7 mm per year (Mather 2007), one of the highest rates along the South African and Namibian coastlines. This is due to the warming Agulhas current (Mather, Garland and Stretch 2009). The three sea level rise scenarios chosen for adaptation planning were 300, 600 and 1,000 mm based on 100 years of current SLR, an accelerated rate at double existing SLR, and an upper scenario of 1,000 mm loosely based on the IPCC 2007 upper scenarios, but including accelerated ice melt.

53.4.2 Municipal Adaptation Plans for the Coastal Sector

Once the extent of different SLR scenarios had been mapped out along the city shoreline, the assessment of the different impacts could be evaluated at a broad level. From this, a set of municipal adaptation plans for the coastal sector where complied as shown in Table 53.2. Using a multi-criteria approach these were ranked into high, medium and low priorities.

Table 53.1 Stormwater municipal adaptation plans (Adapted from Environmental Resources Management South Africa 2009)

Ref	Sub-category	Impact	Intervention	Implementation plan (including policy framework for addressing issue)	Outcome	Priority	Responsible parties (*First listed = lead*)	Resources available (within lead party)	Funding Source	National and Provincial Support	Alignment with IDP
W1	Infrastructure protection (new)	Flooding	Detailed analysis of latest rainfall/run off projections and modeling of systems to be finalised	University of KwaZulu-Natal to finalise detailed analysis of quinary level projections. Water sector officials to work with researchers to understand the nature of and how to interpret results. Expand municipal raingauge network by 30 gauges	Improved understanding of the impacts of climate change on rainfall and run off and identification of particularly vulnerable areas	High	*University of KwaZulu-Natal*, EPCPD, Coastal, Stormwater and Catchment Management	Available as work in progress	The University work is funded by the Water Research Commission (National). The rain gauge network by the eThekwini Municipality	The University work is funded by the Water Research Commission (National)	Plan 1: Sustaining our Natural and Built Environment Plan 3: Quality Living Environments

W2	Infrastructure protection (new)	Flooding	Revise rainfall data in line with latest projections (as of 30 September 2009) and review every 5 years	Coastal, Stormwater and Catchment management officials to commission revision of rainfall data for Durban based on projections as of 30 September 2009. Revised report to be published on eThekwini Municipality website	Impact of climate change on rainfall patterns, flooding and run off embedded into surveys, planning and designs. New infrastructure to be designed to manage increased run off/reduced water availability. Increased resilience of Durban's infrastructure and development to extreme weather patterns	High	*Coastal, Stormwater and Catchment Management,* Coastal Policy	In house	eThekwini Municipality	None	Plan 1: Sustaining our Natural and Built Environment Plan 3: Quality Living Environments

(continued)

Table 53.1 (continued)

Ref	Sub-category	Impact	Intervention	Implementation plan (including policy framework for addressing issue)	Outcome	Priority	Responsible parties *(First listed = lead)*	Resources available (within lead party)	Funding Source	National and Provincial Support	Alignment with IDP
W3	Infrastructure protection (new)	Flooding	Elevate flooding annexure to Council Policy	Write covering report and submit to Council	Enables more sustainable development in Durban. Reduce risk of flooding to property. Will ensure that the implications of climate change are placed at the forefront of spatial land use planning considerations and will help ensure that any planning proposals or development approvals complement the adaptation interventions in this plan	High	*Coastal Stormwater and catchment management,* Coastal Policy	In house	eThekwini Municipality	None	Plan 3: Quality Living Environments

W4	Infrastructure protection (existing)	Flooding	Reduce risk to development in flood plains through amendment of Bylaw 5.2 (2) (iii) to require developments within the 1:100 year floodline within eThekwini boundaries to comply with the Flooding Annexure	Coastal, stormwater and Catchment management and Legal officials to produce an appropriate Bylaw for adoption by Council	Compliance of the Flood Annexure will ensure revised rainfall data and hence climate changes are incorporated into planning and designs	Medium	*Coastal Stormwater and catchment management,* Legal Department	In house	eThekwini Municipality	None	Plan 3: Quality living environments
W5	Infrastructure protection (new)	Flooding	Develop Master Drainage Plans for all river catchments within eThekwini Municipality	Based on rainfall projections revise 1:100 and 1:50 year floodlines to take into account revised rainfall and run off data. Identify priority area foe intervention to reduce risks	Impact of development on flow better understood and reduced. Floodlines reflect flood risks modified by climate change influences on run off. Newly identified developments potentially at risk required to comply with the Flooding Annexure and become more resilient to climate change. Better alignment of planning and risk	High	*Coastal Stormwater and catchment management*	In house	eThekwini Municipality (some work previously funded by USAID)	None	Plan 3: Quality living environments

(continued)

Table 53.1 (continued)

Ref	Sub-category	Impact	Intervention	Implementation plan (including policy framework for addressing issue)	Outcome	Priority	Responsible parties *(First listed = lead)*	Resources available (within lead party)	Funding Source	National and Provincial Support	Alignment with IDP
W9	Infrastructure protection (existing)	Flooding	Protect and restore riparian vegetation so as to protect integrity of river banks and retain biological buffers against flooding	Initiate a "Working for Rivers" programme on a catchment by catchment basis	Reedbeds and wetlands retained. Ecosystem services secured. Reduced risk of flooding to residential and public property	High	*Coastal Stormwater and catchment management*	None at present	To be identified	Provincial support through "Working for Water' programme	Plan 1: Sustaining our Natural and Built Environment
W10	Infrastructure protection (existing)	Flooding	Ensure Asset Management Plans consider revised rainfall/run off data in assessment of the condition of stormwater and catchment management assets	Develope asset management plans and programme for replacement in order of prioirity	Drainage infrastructure capable of managing increased run off (i.e. bigger pipes). Prioritisation across projects with regards to urgency and impacts	Medium	*Coastal Stormwater and catchment management*	In house	eThekwini Municipality National Govt funds	National Asset Management Act	Plan 3: Quality living environments

W12	Infrastructure protection (existing)	Flooding	Reduce stormwater run off from the urban landscape through amendment to the Town Planning Scheme Controls to incorporate fixed parameters for run off reduction	Develop overarching control to ensure compliance with the stormwater management plan which states that developments may not harden more than 40% of their total area and to encourage installation of green roofs, retention/wet basin, detention/dry basin, infiltration basins, etc. Identify existing controls in all areas which need to be repealed to remove conflict. Liaise with Town planning to ensure public acceptance of changes and correct planning	Reduce run off in urban areas, reduced intensity of flood peaks. Increased in recharge of ground water resources	High	*Coastal Stormwater and catchment management* Land use management section	In house	eThekwini Municipality	None	Plan 1: Sustaining our Natural and Built Environment

(continued)

Table 53.1 (continued)

Ref	Sub-category	Impact	Intervention	Implementation plan (including policy framework for addressing issue)	Outcome	Priority	Responsible parties *(First listed = lead)*	Resources available (within lead party)	Funding Source	National and Provincial Support	Alignment with IDP
W13	Infrastructure protection (existing)	Flooding	Public awareness of the benefits of green roofs, retention/ wet basin, detention/ dry basin, infiltration basins, etc. for reducing run off	Implement pilot projects within the municipality to demonstrate benefit of intervention. Develop public awareness programme	– Reduce run off from existing infrastructure in urban areas. Increase in green areas in city	Medium	Environmental Management Department, Coastal Stormwater and Catchment Management, Water and Sanitation, Architectural Department	None at present	eThekwini Municipality	None	Plan 3: Quality living environments
W14	Infrastructure protection (existing)	Flooding and Sea Level Rise	Relocate informal settlements which are highly vulnerable to flooding and sea level rise	– Housing dept to be provided with revised floodlines and coastal set back data – Housing dept to review priority informal settlements and low cost housing for relocation in light if revised flood and coastal set back lines – Review to be carried out every 5 years based on population growth and subsequent revisions to flood lines and coastal set back lines	– Priority relocation list more accurately reflects populations at risk – Reduced number of people living in the flood risk area.	High	*Housing,* Coastal Stormwater and catchment management, Coastal Policy	In house, in the normal course of business	Every 5 years from 2010	National Housing Programme	Plan 1: Sustaining our Natural and Built Environment Plan 3: Quality living environments Plan 4: Safe, Health and Secure Environment

W15	Infrastructure protection (existing)	Flooding and Sea Level Rise	Protection of municipal infrastructure (e.g. transport, storm water, sewerage, electric etc.)	Identify key assets at risk following the development of: – Master drainage Plans(W5) – Shoreline Management Plans (W8) – Asset Management Plans (W10&11)	Better understanding of highly vulnerable assets/ infrastructure – Reduced risk to infrastructure – Opportunities to implement new, efficient, low emissions technology – simultaneous protection of private properties	High	Coastal Stormwater and catchment management, Coastal Policy	In house, in the normal course of business	Initial review by end June 2010, subsequent reviews every year as plans are developed	National disaster funding	Plan 1: Sustaining our Natural and Built Environment Plan 3: Quality living environments

Table 53.2 Coastal municipal adaptation plans (Adapted from Environmental Resources Management, South Africa 2009)

Ref	Sub-category	Impact	Intervention	Implementation plan (including policy framework for addressing issue)	Outcome	Priority	Responsible parties *(First listed = lead)*	Resources available (within lead party)	Funding Source	National and provincial support	Alignment with IDP
W6	Infrastructure protection (new)	Sea Level Rise	Revise coastal set back lines	Determine and demarcate the High Water Mark based on sea level rise modeling and revise coastal set back lines accordingly	Coastal set back lines modified for climate change influence on sea level and storm surges	High	*Coastal Policy* Coastal stormwater and catchment management	In house, in the normal course of business	None	None	Plan 1: Sustaining our Natural and Built Environment
W7	Infrastructure protection (new)	Sea Level Rise	Develop council policy and by-laws or scheme controls covering development within coastal set back lines	Coastal policy officials to	– Developments potentially at risk through a climate induced increase in sea levels and storm damage required to adhere to the requirements of the Coastal council policy and become resilient to climate change	Medium	*Coastal Policy*	In house, in the normal course of business	None	None	Plan 1: Sustaining our Natural and Built Environment

				– Draft policy – Discuss potential bylaws or scheme controls – Report to be submitted to infrastructure committee and Exco and published for public comment	– Will ensure the implications of climate change are placed at the forefront of spatial land use planning considerations and will help ensure that planning proposal or development approvals complement the adaptation interventions listed in this plan		Legal dept				
W8	Infrastructure protection (new and existing)	Sea Level Rise	Prepare Coastal Management Plans for the entire Durban coastline	Identify and prioritise coastal areas at highest risk from strom damage and flooding using sea level rise model Prepare Shoreline and Estuary Management Plans for whole Durban coastline (focusing initially on Central Beachfront, Amanzimtoti, Bluff dunes and Umhloti)	– Detailed understanding of the impacts of coastal storms and flooding on coastline – Mitigation of risk through prevention, reduction and adaptation – Rehabilitation plans following storm events – Better management of estuaries	High	*Coastal Policy*	In house, in the normal course of business	None	None	Plan 1: Sustaining our Natural and Built Environment

Table 53.2 (continued)

Ref	Sub-category	Impact	Intervention	Implementation plan (including policy framework for addressing issue)	Outcome	Priority	Responsible parties *(First listed = lead)*	Resources available (within lead party)	Funding Source	National and provincial support	Alignment with IDP
W11	Infrastructure protection (existing)	Sea Level Rise	Ensure assets management plans consider revised sea level rise scenarios in assessment of the conditions of coastal assets	Develop asset management plans and programme for replacement in order of priority	– Drainage infrastructure capable of managing increased run up – Prioritisation across projects with regards to urgency and impact	Medium	Coastal Policy	In house, in the normal course of business	None	None	Plan 3: Quality living environments
W14	Infrastructure protection (existing)	Flooding and Sea Level Rise	Relocate informal settlements which are highly vulnerable to flooding and sea level rise	– Housing dept to be provided with revised floodlines and coastal set back data – Housing dept to review priority informal settlements and low cost housing for relocation in light if revised flood and coastal set back lines – Review to be carried out every 5 years based on population growth and subsequent revisions to flood lines and coastal set back lines	– Priority relocation list more accurately reflects populations at risk – Reduced number of people living in the flood risk area.	High	Housing, Coastal Stormwater and catchment management, Coastal Policy	In house, in the normal course of business	None	None	Plan 1: Sustaining our Natural and Built Environment Plan 3: Quality living environments Plan 4: Safe, Health and Secure Environment

W15	Infrastructure protection (existing)	Flooding and Sea Level Rise	Protection of municipal infrastructure (e.g. transport, storm water, sewerage, electric etc.)	Identify key assets at risk following the development of:) – Master drainage Plans(W5) – Shoreline Management Plans (W8) – Asset Management Plans (W10&11)	Better understanding of highly vulnerable assets/ infrastructure – Reduced risk to infrastructure – Opportunities to implement new, efficient, low emissions technology – Simultaneous protection of private properties	High	Coastal Stormwater and catchment management, Coastal Policy	In house, in the normal course of business	None	None	Plan 1: Sustaining our Natural and Built Environment Plan 3: Quality living environments

53.5 Challenges and Distractions

A number of key challenges were identified during the development of the MAPs. First, it is difficult to justify the use of limited resources in responding to a change that may or may not occur in the future, when the immediate needs of the present are so great. People in Durban are struggling to meet basic needs given the high rates of unemployment, HIV/AIDs infection and significant infrastructural backlogs (e.g., housing).

A further key challenge is the need to develop political and technical champions for these projects. As the political head of the municipality, the mayor of Durban, Cllr. Obed Mlaba, has risen to this challenge, providing strong political leadership in the field of climate change. Champions on the technical side have been more difficult to come by as the range of adaptation measures required crosses several disciplines. The dilemma faced by EPCPD (the department spearheading the municipality's adaptation work) was to either learn the 'language' of each discipline or to 'convert' existing key staff in the targeted departments into champions for adaptation and change through a process of engagement and project development. The latter has proved to be the most fruitful approach, as the process of change is much easier to effect when the momentum is internally driven. This has enabled adaptation work to roll out quickly where these 'converts' exist.

A critical element in advancing the adaptation agenda has been to look for adaptation opportunities that could be created from work that was already ongoing within the various sectors. This approach yielded a number of interventions that could already be classified as adaptation measures, and that could be highlighted as examples of good practice. In so doing, the technical staff has found ways of including adaptation to climate change into existing business plans, projects and commitments without having to label it as such. This has also assisted departments in understanding that responding to climate change is not a new and foreign obligation, but is in fact closely aligned with the day-to-day assessment of risks and impacts usually undertaken. This approach has highlighted the fact that by modifying traditional approaches to risk assessment slightly, the twin goals of adaptation and good design are often easily achieved. This has spurred departments to look at the rest of their day-to-day activities to assess what additional adaptation measures could be mainstreamed into design processes.

A key question related to any proposed change to municipal delivery systems is what will it cost and who will pay? A better question to ask, however, is Can we afford to lose existing infrastructure, and what are the broader social, environmental and economic costs associated with such a failure? This question is easily addressed if an asset management approach is adopted that addresses the costs and risks of failure by evaluating the infrastructure over its lifespan, thereby providing an objective and balanced way of evaluating 'costs.'

Another difficult question is who protects the public and private assets that are at risk. As a public authority, the decision to defend or retreat has to be tempered by lifecycle costing. New infrastructure may need to be protected for some time to come, while older infrastructure may need to be relocated and, in the process, updated to more efficient technology. However the protection of private assets is one area where considerable debate exists. Many private landowners cannot afford to protect their homes located along the shoreline and are looking to government for protection. South Africa's new Integrated Coastal Management Act makes it clear that the government is not responsible for protecting private property; however, it is likely that this will be tested in court in the next few years. An additional and related complication is that by introducing climate change considerations into the development approval process, every architect or developer now wants an explanation as to why approval requirements are being made more stringent. This adds to the workloads of the already stretched technical staff.

One of the most difficult issues facing the municipality is how it must respond when shorelines erode and municipal infrastructure erected to service private properties is no longer possible due to land erosion. The obligation to provide services in locations where they may become unviable due to loss of land along the coast or river is an area that is not fully understood at this time.

At a more macro level, a further challenge to the programme has been finding sources of funding for the necessary studies on climate change. Limited funding has been available from the municipal budget due to the fact that climate change is not yet fully mainstreamed within municipal operations. Furthermore, international funding is often difficult to access due to the extensive and complicated paperwork required.

During the adaptation planning and subsequent roll out of projects a number of important issues were raised ranging from questions relating to the science of climate change, to detailed questions relating to technical processes.

A shortage of technical staff with the capacity to implement climate change work has been a challenge even in a well resourced municipality such as Durban. It also requires time and effort to understand climate change science and the possible impacts of climate change impacts on the city. Time is often not a luxury available to staff who are continuously 'putting out fires' and involved in crisis management. The shortage of technical staff means that most of the climate protection work undertaken is reactionary. There is thus little time for proactive planning and implementation.

Because politicians get elected every 5 years, they tend to adopt a short term focus, pushing for actions that show immediate results, which improve their prospects for re-election. The hard decisions related to climate change adaptation are put off in fear of losing votes and re-election. However, given the groundswell around the issue of climate change, the next municipal elections could well see climate change as a key voting issue.

A significant distraction during the adaptation planning process has revolved around the quantum of climate change likely to be experienced in the Durban area. One of the difficulties facing the engineering sectors of the city was to determine what scenarios are possible and what figures should be used in their design calculations. While it is understood that it is not be possible to determine an exact number, the range of answers emerging from the climate change projections make it impossible to act with any degree of professional comfort.

Specifically in the area of sea level rise, the two largest areas of debate were around the variations and uncertainly in SLR predictions. Mindful that these two issues have the potential to derail any worthwhile progress on the project, it was decided to base the adaptation planning work on what is believed to be a reasonable evaluation of potential SLR scenarios given the current state of the science. Any higher figure of SLR (i.e., 5 m) was likely to result in a failure to obtain stakeholder buy-in, as the scenarios would have likely been dismissed as unbelievable. It is clear that this type of work will require regular updates as more information becomes available.

53.6 Conclusions: Lessons Learnt and Key Success Factors

Through the process of engagement with officials, politicians and the public, a number of lessons have been learnt. Three key success factors in achieving a successful adaptation plan for Durban are highlighted below:

Leadership: Strong leadership at a number of levels was a signature quality of this process. At a political level, this was achieved by the championing of the climate change debate by the Mayor, and supported with strong technical input by officials in the fields of environment, engineering, health and disaster management.

Technical excellence: The technical staff, consisting of a mix of academics, consultants and in-house specialists, all of whom were recognised leaders in their respective fields, were able to focus on a technical agenda and deliver credible and realistic work plans. Arising out of this partnership, new research into the local downscaled impacts of climate change has lead to innovative and pioneering climate tools being developed for the first time in the city.

Communication: Throughout the process, continuous engagement with stakeholders has helped in the communication of issues of concern and helped to gain the public's trust in the process. A hallmark of the process has been providing the right type of information in a useable form in order to help stakeholders understand the risks involved. Cross sector dialogue is also critical in ensuring that adaptation in one sector does not have a negative effect on another. For example, when investigating ways of harvesting the rainfall in the new housing program through the installation of rain water tanks, health officials raised a concern regarding projected temperature increases and the associated migration of the malaria belt southwards. The proposed water tanks, if not installed with adequate insect control, would increase the threat of malaria.

The path to climate change adaptation planning is beset with all manner of obstacles. However, with the right expertise, political support and appropriate communication, the roll out of a successful adaptation plan can be achieved even in the context of limited resources and high level development pressures.

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Glossary

The following terms have been adapted from the glossary of the Intergovernmental Panel on Climate Change, Fourth Assessment Report (2007),[1] unless otherwise indicated.

Adaptation Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist; e.g., anticipatory and reactive, private and public, and autonomous and planned. Examples are raising river or coastal dikes, the substitution of more temperature shock resistant plants for sensitive ones, etc.

Adaptive capacity The whole of capabilities, resources and institutions of a country or region to implement effective adaptation measures.

Climate change A change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/ or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

Climate change impact The effects of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts: Potential impacts are all impacts that may occur given a projected change in climate, without considering adaptation. Residual impacts are those impacts of climate change that would occur after adaptation.

Climate prediction The result of an attempt to produce an estimate of the actual evolution of the climate in the future, for example, at seasonal, interannual or long-term time scales.

Ecohealth approach An approach to human health that identifies the web of ecologically- based factors affecting human health – as well as the links between them.

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[1] Accessed via: http://www.ipcc.ch/publications_and_data/ar4/wg1/en/annex1.html

K. Otto-Zimmermann (ed.), *Resilient Cities: Cities and Adaptation to Climate Change Proceedings of the Global Forum 2010*, Local Sustainability 1,
DOI 10.1007/978-94-007-0785-6,

Equipped with this knowledge, local communities can better manage ecosystems to improve people's well-being and the health of the ecosystem.[2]

Ecosystem-based adaptation (EBA) The adaptation policies and measures that take into account the role of ecosystem services in reducing the vulnerability of society to climate change.[3]

Food security Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs, as well as to culturally acceptable food preferences for an active and healthy life. The multi- dimensional nature of food security includes food availability, access, stability and utilization.[4]

Local government An *administrative body* or system in which political direction and *control* is exercised over the *community* of a *city*, town or small district.[5]

Mainstreaming The process of integrating policies that seek to address climate change concerns in regular development planning and ongoing sectoral decision making.

Mainstreaming specifically means that development policies that otherwise would not have taken climate mitigation and adaptation into consideration, would explicitly include these concerns in the formulation and implementation processes.[6]

Mitigation Technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce greenhouse gas emissions and enhance sinks.

Resilience The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change.

Resilient city A city that supports the development of greater resilience in its institutions, infrastructure, and social and economic life. Resilient cities reduce vulnerability to extreme events and respond creatively to economic, social and environmental change in order to increase their long-term sustainability. Resilient city

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[2] Gopalon H.N.B., UNEP Division of Policy Development and Law http://www.unep.org/ourplanet/imgversn/images/Gopalan_ecohealthv3.pdf

[3] Vignola R, Locatelli B, Martinez C, Imbach P (2009) Ecosystem-based adaptation to climate change: What role for policy-makers, society and scientists? Mitig Adapt Strateg Glob Change 14:691–696

[4] FAO: http://km.fao.org/fsn/resources/glossary0/en/

[5] European Environment Agency: http://glossary.eea.europa.eu

[6] Chuku (2010) Pursuing an integrated development and climate policy, framework in Africa: options for mainstreaming. Mitig Adapt Strateg Glob Change 15:41–52

activities are sensitive to distinctive unique local conditions and origins. Efforts undertaken to prevent crisis or disaster in one area should be designed in such a way as to advance the community's resilience and sustainable development in a number of areas. As such, resilient cities define a comprehensive 'urban resilience' concept and policy agenda with implications in the fields of urban governance, infrastructure, finance, design, social and economic development, and environmental/resource management.[7]

Risk The expected losses (of lives, persons injured, property damaged and *economic activity* disrupted) due to a particular *hazard* for a given area and reference period. Based on mathematical calculations, *risk* is the *product* of *hazard* and *vulnerability*

Risk in environmental context means likelihood, or *probability*, of *injury*, *disease*, or death resulting from *exposure* to a potential *environmental hazard*.[8]

Sea level rise An increase in the mean level of the ocean. Eustatic sea-level rise is a change in global average sea level brought about by an increase in the volume of the world ocean. Relative sea-level rise occurs where there is a local increase in the level of the ocean relative to the land, which might be due to ocean rise and/or land level subsidence. In areas subject to rapid land-level uplift, relative sea level can fall.

Storm surge The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place.

Sustainable development A form of development that meets present-day needs without compromising the ability of future generations to satisfy their own requirements. It aims to improve individuals' living conditions whilst preserving their environment in the short, medium and – above all – long term. The objective of sustainable development is threefold: development that is economically efficient, socially fair and environmentally sustainable.[9]

Urban heat island (UHI) The relative warmth of a city compared with surrounding rural areas, associated with changes in runoff, the concrete jungle effects on heat retention, changes in surface albedo, changes in pollution and aerosols, and so on.

Urban greening The planned, integrated and systematic approach to managing urban and peri-urban vegetation. Urban greening aims to contribute to the environmental, psychological, sociological, and economic well-being of urban society.[10]

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[7] Resilient Communities Program Concept 2002

[8] European Environment Agency: http://glossary.eea.europa.eu

[9] European Commission: http://europa.eu/scadplus/glossary/sustainable_development_en.htm

[10] European Tropical Forest Research Network (ETFRN): http://www.etfrn.org/etfrn/newsletter/nl22_disc.html

Urbanization The conversion of land from a natural state or managed natural state (such as agriculture) to cities; a process driven by net rural-to-urban migration through which an increasing percentage of the population in any nation or region come to live in settlements that are defined as 'urban centres'.

Vulnerability The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Water stress The available freshwater supply relative to water withdrawals acts as an important constraint on development. Withdrawals exceeding 20% of renewable water supply have been used as an indicator of water stress. A crop is water-stressed if soil- available water, and thus actual evapotranspiration, is less than potential evapotranspiration demands.

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