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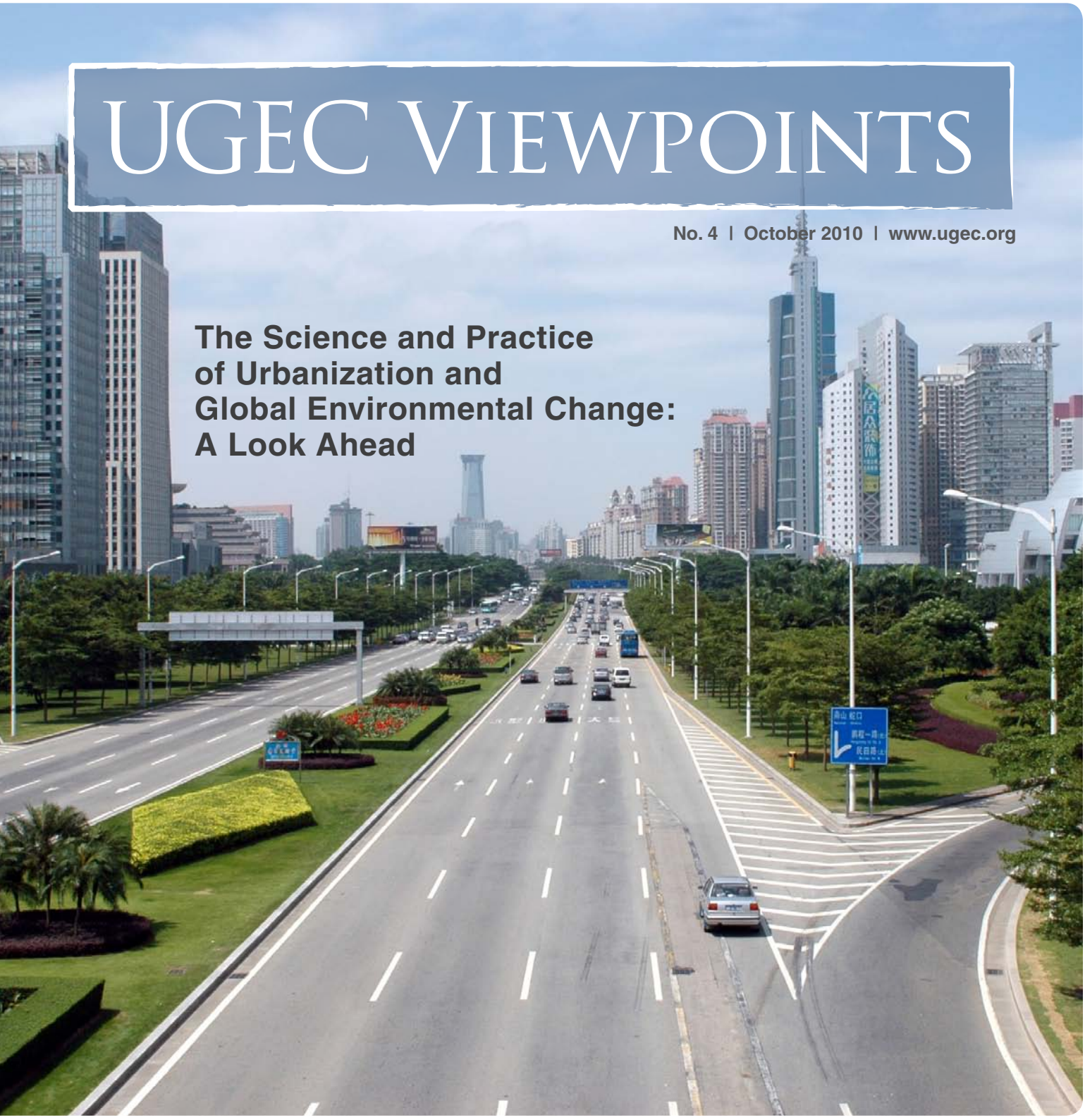
The Science and Practice of Urbanization and Global Environmental Change: A Look Ahead



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Editorial

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Dear friends of the UGEC project,

This fourth issue of the UGEC *Viewpoints* that you are reading (online or in print) marks the half way point of the UGEC project lifespan. It is thus appropriate that the issue is dedicated to a reflection over current thinking about the future of UGEC science and practice – both the second phase of the project and beyond. It includes contributions from both founding project members, but also more recent project associates who have enriched current research by bringing forward a thematic and regional diversity within the UGEC community. For this issue, we asked each contributor to share their thoughts on future directions and needs in the examination of the bidirectional interactions and feedback loops between urbanization and global environmental change. As you will discover, the contributors provide several new perspectives, revealing new ways of thinking that can drive – but also arise from – UGEC research in the next decade.

The issue opens with an essay by Roberto Sánchez-Rodríguez on the current standing of UGEC research, its future paths and the role of the UGEC project in the much needed science-policy interfacing. Peter Marcotullio and Bill Solecki advance the renewed debate over the definition of urban areas and urbanization in the context of the global environment. Broadening the view of urban systems, David Simon explores the implications of the observed international integration of urban systems for global environmental change. Harriet Bulkeley focuses on the urban governance theme by looking at the complexities and challenges of governance of climate change in urban areas through local responses to projected impacts. Shuaib Lwasa reviews the research needs on the themes of vulnerability and adaptation to climate change in urban areas for Africa. Karen Seto and Peter Christensen promote the use of advanced remote sensing tools for decomposing the "urban black box". Finally, I summarize a recent science-practice dialogue on the emerging trends for the new science of adaptation to climate change in urban areas.

Many of you will be reading this issue of UGEC *Viewpoints* during our International Conference on Urbanization and Global Environmental Change: *Opportunities and Challenges for Sustainability in an Urbanizing World* (www.ugec2010.org) in Tempe, Arizona. This timely conference hosts a wide spectrum of scientists, practitioners, policymakers and stakeholders who have been invited to participate in a forum for reflection and exchange of knowledge, experiences, lessons, ideas and information on the multifaceted interactions between urban areas and global environmental change. We hope that in addition to the plenary and parallel session discussions, this issue will give you starting points for discussions with other conference participants and the authors of the contributions.

We hope you will enjoy reading this fourth issue of Viewpoints; we ask you to please circulate widely the pdf copy that can be found on our website. www.ugec.org. The next issue will be published in early 2011 summarizing and elaborating upon the proceedings of plenary and parallel sessions from the UGEC 2010 conference.

Best regards,

Michail Fragkias
UGEC Executive Officer

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Haifa Beach, Israel

Rediscovering Urban Societies in the 21st Century: A Role for UGEC

Roberto Sánchez-Rodríguez

We live in an era of intense transformations that challenge the present and future of societies. Although throughout history mankind has gone through dramatic social and environmental changes, the intensity and extent of current global and regional problems and their interactions with local processes have characteristics and proportions that have never before been reached. Urban areas play a central role in those transformations and challenges, as the world population has become predominately urbanized, and urban areas have become key nodes of global, regional, and local socioeconomic and biophysical processes (Marcotullio and McGranahan 2007; Martine et al. 2007; Grimm et al. 2008). A better understanding of urban areas and their interactions with global environmental change can assist societies in addressing current and future local, regional and global challenges for humanity.

Efforts in this direction should take advantage of the rich tradition in urban studies that have generated an impressive amount of disciplinary knowledge. Missing so far are multidimensional and integrated perspectives and approaches for the study of dynamic and complex urban processes. The call for interdisciplinary and integrated perspectives of urban areas is not new. It has been about 40 years since Blair (1973) alerted the need for transcending unidimensional perspectives based on physical planning and progressing towards multidimensional approaches for urban areas. Other scholars have followed suit and have highlighted the importance of interdisciplinary perspectives in the study and management of urban areas (Hohan 1993; Simmie 2003). Unfortunately, those calls have had little success so far. Urban problems are still often studied and addressed unidimensionally.

The study of the bidirectional interactions between urban areas and global environmental change opens the opportunity to develop new ways of thinking about urban areas. The ways in which urban problems and research topics are defined take on completely different meanings when they are addressed on an interdisciplinary or transdiciplinary basis. This implies recognizing that urbanization is influenced not only by local, but also by global and regional socioeconomic processes that modify the natural landscape. The confluence of those processes occurring at different geographical and temporal scales creates multiple

interactions among the social, economic, cultural, political, physical, and ecological dimensions of urbanization. The extent and pace of those interactions in the 21st century have a strong impact on the characteristics of urbanization and opportunities for sustainability. It is through these multidimensional perspectives that the interactions between urban areas and global environmental change can become tangible to researchers, decision-makers, practitioners, and stakeholders.

Climate change provides a good opportunity for expanding our understanding of the interactions between urban areas and global environmental change. Building responses to climate change in urban areas should recognize the bidirectional interactions between urban areas and biophysical processes. The growing number of initiatives in this direction over the last five years focused mostly on mitigation strategies and actions (understanding how urban areas contribute to climate change and formulating actions for mitigation). However, over the last two years, reduction of vulnerability and adaptation to climate change have emerged as important elements of the urban response to climate change (addressing climate change impacts on urban areas). Central to that effort is the capacity to understand not only individual impacts of climate change (i.e. the impacts of temperature increase on health or drinking water supply, distribution and quality); but also how those problems interact dynamically with urban processes (rate and type of urbanization, poverty and social inequality, characteristics of the built environment, availability and type of ecosystem services, etc.), and the cumulative effect of those interactions in time and geographical space. This knowledge will help construct better perspectives of complex problems in urban areas useful to the design of policies and responses to the challenges societies face in the 21st century. However, a note of caution is in order. Building these integrated perspectives is not an easy task and should not be considered as an outcome of one single effort. Rather, this should be regarded as a continuously evolving, learning process.

The Urbanization and Global Environmental Change project (UGEC) provides an integrated research framework contributing to that learning process. It is a framework through which individual and institutional projects expand our understanding of the complex and dynamic interactions between urbanization and global environmental change. Although UGEC has a specific focus on those interactions, the potential exists for developing new ways of thinking about urban areas. Its emphasis on a multidimensional understanding of those interactions at different geographical scales (from global to local) contributes to developing new approaches for research and practice.

There are two important tasks in the second phase of the UGEC project: (i) strengthen its scientific agenda through new multidimensional conceptual and methodological frameworks; and (ii) make its science relevant to practitioners, decision-makers, stakeholders, and the rest of the scientific community. Both issues are interrelated and require a concerted effort from the UGEC community.

The development of new conceptual frameworks requires creative and innovative research. One of the challenges we face is to overcome our disciplinary cultures in the design of research projects and to conceive integrated perspectives of complex problems. Working with multiple interactions among social processes and environmental issues operating at different geographical and temporal scales will imply building conceptual frameworks that can be progressively updated and improved. It implies redefining our research topics and learning how the different dimensions operate in the urban space. It is often not a lack of knowledge of these dimensions, but rather needing to develop a better understanding of how they work together. UGEC seeks to set precedents that can foster new ways of thinking about urban areas and global environmental change. However, care should be given to recognize the heterogeneity of urban areas and their interactions with global environmental processes across regions. There are significant differences among

Kibera, the largest slum in Nairobi; second largest slum in Africa

Bicycle commuting

urban areas in high-income countries compared to those in middle-income or low-income countries. Urban areas reflect the conditions, needs, and characteristics of the societies within which they are built and research frameworks and development projects should respond to those particular conditions.

Making UGEC's science relevant to practitioners, decision-makers, stakeholders and the related scientific communities also involves creativity and innovation. The divide between the scientific community and urban actors shaping urban growth has been a major obstacle for creating practical applications from the wealth of research available and produced by the scientific community. The needed steps towards building communication, trust, and collaboration between the domain of science and the domain of practice have been explored by a number of scholars (Roux et al. 2006; Turnhout et al. 2007). UGEC can make contributions in this direction, from helping practitioners develop a better understanding of global environmental change, to influencing the design and implementation of urban sustainability. Multidimensional approaches mentioned above can become an efficient tool connecting current urban and environmental problems with global environmental change. This can help practitioners, decision-makers, and stakeholders understand the importance of those relationships and the need to address them in order to create comprehensive strategies for urban sustainability. This can also set precedents for other research communities to follow, improving our understanding of urban and global environmental changes.

I mentioned above that current international attention to climate change creates opportunities for rediscovering urban societies in the 21st century. Attention to urban areas was neglected in the climate change debate over the last decades, but in the last five years, urban areas have been given unprecedented attention, bringing a new dimension to this debate. This has created a growing interest in national and local governments to create urban responses to climate change (mitigation and adaptation). This momentum creates opportunities to redefine our understanding and knowledge of urban areas and their interactions with global environmental change. It also opens windows of opportunity for making research in this area relevant to urban practitioners, decision-makers, and stakeholders. Yet, the same momentum has inherent risks. The current rush to create urban responses to climate change will require rapid responses from the scientific community. Otherwise, the gap between science and practice mentioned above, could widen, as decisions could potentially be made based on incomplete or fragmented information and knowledge, despite good intentions. In order to rediscover urban societies in the 21st century, we need to better understand them. But for some of us, it might also mean finding new roles as scientists in society.

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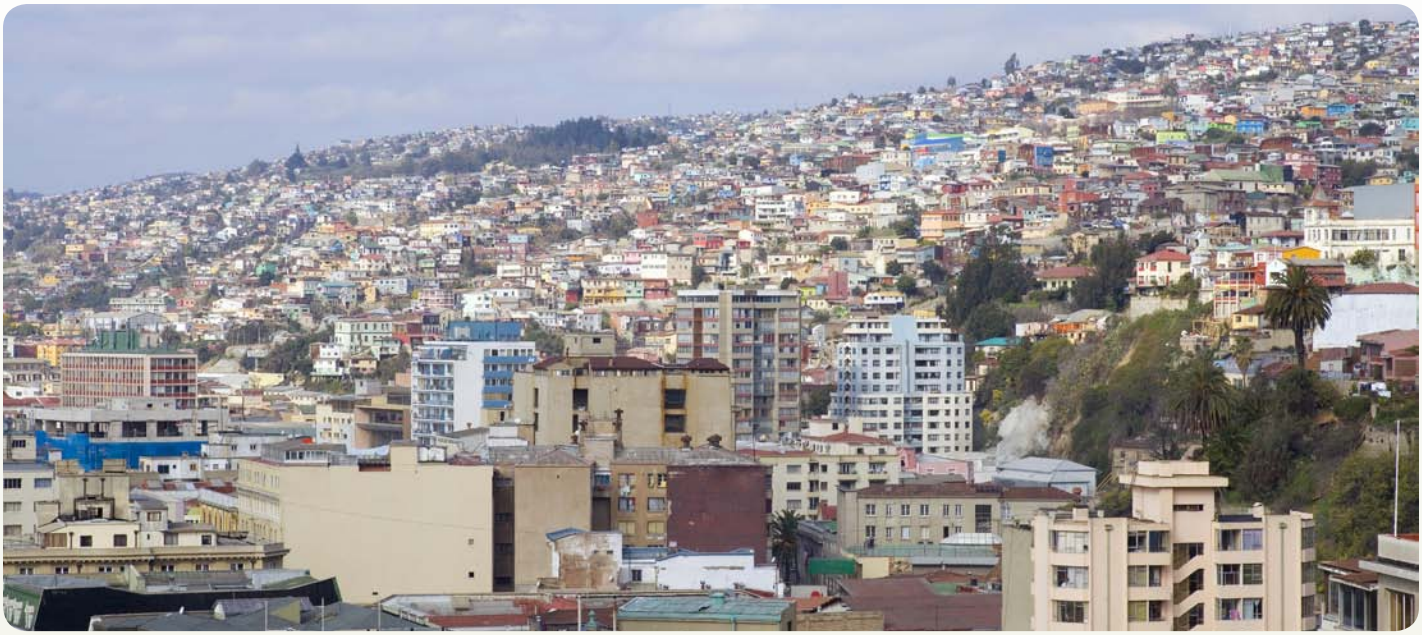

Dense construction in Valparaiso, Chile

What is a City? Old Debate, New Implications

Peter J. Marcotullio & William Solecki

The debate over the definition of "urban" and the elements of the urbanization process has a long history. This discussion has been embedded in both within intellectual discourse and social and political tensions, and together, highlights the distinction between cities as social entities and cities as social qualities. With increasing interest in environmental concerns and resource management, the argument over what is a city and the process of urbanization has once again emerged as a major issue, despite the advent of new technologies such as remote sensing, geographical information systems, and global positioning systems that potentially help to identify the physical shape and structure of cities. While the new debate is now focused on biophysical issues, it still revolves around the entity versus quality characteristics of cities. There is much that environmental and ecological studies can bring to the definition of the city, but a clearer focus on this issue is necessary.

What we mean by urban is important, not just to enhance comparative work. It is necessary for a deeper understanding of the environmental benefits and costs of dense settlement. We believe, however, that it is critically important to assess what those in the urbanization and environment research community and practitioner community could learn from long-standing definitions and conceptions of the city, if not from the debate in general. Moreover, urbanization and environmental change research can now add much to our notions of cities and what constitutes the urbanization process.

This opinion piece first discusses some of the different definitions of the city and urbanization used in the social science literature. We then turn to environmental research and show that there are some commonalities between these definitions and that of the social science literature. We also argue that the new technologies in urban environmental scholarship do not fulfill the promise of easy definitions. At the same time, there are some powerful models and analytic frameworks that are emerging from the urbanization and environmental change literature that can add much to our knowledge of cities, if we focus on both the social

and ecological qualities. We conclude with some comments on why this debate is so important and must continue and evolve.

Urban definitions and perspectives in the social science literature

It has never been easy to define what a city is and even more difficult to identify the determining characteristics of one that is applicable to all of urban history (Carter 1983). Recent studies suggest that given varying contemporary forces of urban change, urbanization processes are currently acting on cities differentially, creating new and different types of cities, never seen before (Marcotullio 2005). As in the past, the definition of a city today is intertwined with the notion of urban origins and inspired by the contemporary forces of change.

In general, definitions of the city can be divided into two main groups: those that focus on the city as an entity and those of the city as a quality (Pacione 2001). Within each of these general categories there have been debates as to what indicator or process is the most accurate in defining urban spaces. For example, with the 'city as entity' set of definitions, scholars have used population size, economic base, administrative criteria and functional definitions. Berry (1973) pointed out that the most widely accepted theories on the effects of cities on social relationships is based upon population characteristics of the city; concentration, size, density and heterogeneity. This is most likely related to the observations, starting with Weber (1967 [orig. 1899]) and culminating with Tisdale (1942) that at some point along the population, size and density scales, villages become towns and towns become cities. Of course, the threshold point varies across time and space.

Besides these characteristics others have used a definition based upon the emergence of a market place, the location of jobs and the urban economic structure. (Weber 1958; Bairoch 1988), administrative aspects (see any biannual UN Publication of World Urbanization Prospects), or functional characteristics (Berry 1973; Friedmann and Miller 1965; McGee 1991).

While the definitions of the 'city as entity' developed and transformed, these definitions could not be used in isolation to identify the impact of the urban on social, behavioral or economic change. These notions were inspired by Wirth (1938), who wrote. the single most widely accepted theory of the effects of cities on behavior and social relations. He theorized that the larger size of cities produces greater volumes of human interaction, which spread interpersonal dependence over more people creating less dependence upon any one person. As a result, contacts become impersonal, superficial and transitory. So for instance, some global cities researchers focus more on the "world city formation process" (Friedmann 1986) and the processes associated with globalization that are occurring with these cities (Taylor 2004; Sassen 1991, 1994) than on the attributes of "global cities" such as the numbers of transnational corporation headquarters, conference buildings, international banks, etc. (Short and Kim 1999; Lo and Yeung 1998). The category of "global city" then is not a yes-no question, but rather is an intensity continuum of sets of urban processes. This view helps researchers provide explanations of change. The questions these researchers ask include: What are the characteristics of processes that promote "global" activities in cities. How are these experiences different among cities and between cities and non-urban spaces.

The world city research agenda is only one of many that have attempted to identify processes and qualities that define the city. Over time, many theories have emerged from the social science disciplines, including sociology, political economy, and post-modernism more recently, that have attempted to explain how cities differ from non-urban spaces, by focusing on their many varying qualities.

The definition of urban in the environmental change literature

Urban environmental studies differ from studies of the social sciences in that for environmental researchers and ecologists, cities have most intensively been conceptualized as entities separate and distinct from "natural" or rural areas. The un-disturbed, non-human dominated "natural" areas have been the primary purview of ecologists and environmentalists for the last 150 years. Recent reviews suggest that this trend continues (Collins et al. 2000; Corbyn 2010). Urban ecology studies, until recently, were seen as non-traditional and have only gained legitimacy in this field by comparing aspects of the urban area to what is found in the "natural" world. Within the ecology and environmental science literature, only very limited attention has been given to the definition of cities; the urban tends to be assumed, not defined (NcIntyre, Knowles-Yanez, and Hope 2000).

That is to say, urban environmental researchers often see cities entirely as entities. As entities, environmental and ecological researchers rely on the definition of city as either by

Shennan Road in Shenzhen, Guangdong Province, China

population or some variant of "built up area," or specific "land use" (residential, commercial, urban, etc) type (NcIntyre, Knowles-Yanez, and Hope 2000). In terms of the first type of definition, the identification of cities as built space is not uncommon. It is typically used by those examining changes in natural systems with increasing urbanization in space-for-time substitution experiments and rural-to-urban transect analyses (McDonnell et al. 1997; McDonnell and Pickett 1991). Alternatively, "urban" is considered in gradients of land use from pristine natural environments to cultivated landscapes consisting of a matrix of agriculture land to suburban landscapes which include low to moderate density housing and urban landscapes of the most intense human influence dominated by building roads and other paved surfaces (Forman and Godron 1986).

These types of studies have been aided by new technologies for geographical information system and satellite imagery analysis to help sort out boundary and other geographical concerns (Skole 2004; Wolman 2004). Several excellent databases can be used to identify urban areas. For example, a recent review demonstrated that there are ten global urban or urban-related maps of urban extents (Schneider, Friedl, and Potere 2009).

While these studies and technologies have provided valuable findings on ecological conditions across space they suffer from the some of the same deficiencies articulated by their social counterparts, namely, 1) defining an area as urban is ultimately an arbitrary decision (Timberlake 2010); and 2) focusing on the 'city as entity' tells us precious little about the processes associated with urbanization that are responsible for change. In the first case, the ten databases that are currently used to identify urban areas globally vary by more than an order of magnitude. So the set that defines the smallest set of populated places suggests that there are 276,000 km2 of urban areas while the largest suggests there are 3,524,000 km2. In the second case, using a single indicator as the definition of a city can result in conflating the many different processes that occur within cities. Hence, rather than exploring the unique contributions of urbanization on environmental change, all aspects of human life, whether they occur within or outside of urban areas, are rolled up into one super variable; the city. The classic example of such a study is the urban ecological footprint (Wackernagel and Rees 1996). Another example, is to use impervious surfaces that arguably can stand alone as a proxy for human environmental impact (Sutton et al. 2009). In these cases, all influences associated with built up areas are potentially "blamed on" urbanization and cities. There is no attempt to separate out the influence of policies, wealth, population or any other potential explanatory variable. The threat is that cities and urban life will be associated with high resource consumption (Brown 2001) without demonstrating that indeed people of similar income, class, status, etc. in cities consume more than those living in non-urban spaces.

In an attempt to supplement the definition of the 'city as entity', some environmental researchers have used the term "urban ecosystem" to identify the qualities of urban areas (Douglas 1981; Millennium Ecosystem Assessment 2005; Sterns and Montag 1974). These types of studies come under the category of "ecology of cities" rather than "ecology in cities" (Grimm et al. 2000). Unfortunately, there are few of these types of studies and even among these, integration between biophysical, and human and economic components is limited (McDonnell, Hahs, and Breuste 2009).

Those that use the urban ecosystem concept argue that cities have ecological structure and functions as do their counterparts in the natural world. Important to urban ecosystem studies are the inclusion of both physical and social dynamics and processes

and the scale of impact (McGranahan, Marcotullio, et al 2005). That is, rather than considering the city as a bounded entity, these studies focus on the activities and processes that occur in urban areas and how they impact environments near and far. Urban ecosystem analyses are based upon an exploration of how these systems differ from other types of ecosystems.

Over the past few years, using the urban ecosystem notion, research frameworks have emerged to integrate the socio-economic dynamics within urban space and relate them to environmental outcomes (Machlis, Force, and Burch 1997). This approach, among others, has been used by the urban long-term ecological research (LTER) stations (i.e., Baltimore and Phoenix). In our minds the most important features of these types of studies is that the ecological and environmental differences between urban and non-urban areas are defined and associated with socio-economic factors in these two types of spaces. In this way, findings point out differences between both the independent variables (socio-economic events and dynamics within different spaces) and are related to the environmental conditions and processes. As such, the social and ecological qualities of cities as influences on environmental and social change are examined. Within these types of studies, we see three areas that address the quality of urbanism and fruitfully cross-fertilize the social and ecological sciences and reflect both the analytical and process elements of cities:

1. Local and global environmental changes analytics - understanding the relative role of local and global change process. The social science literature is rich with studies analyzing the relative role of globalization on localities and connections between local and global socio-economic process. As mentioned, there is a large and diverse literature on globalization and cities. Defining cities using this integrative approach can be useful for urban ecologist and environmental scientists to develop frameworks for understanding the relative role of local process of environmental change and global environmental change such as climate change;

2. Multiple function of cities – cities have long been recognized as serving multiple roles and functions within societies as administrative, religious, and intellectual centers, and, as critical sites for capital accumulation and economic function. As we mentioned in the beginning of this article, there is no one definition that can fit all cities. The focus on the ecological function of cities has further expanded this category to include cities as sites for ecological processes, change and energy flows, both locally and regionally and beyond, as well as sites that can enhance biodiversity through the bringing together of numerous alien species in new flora and fauna assemblages. Defining cities using multiple criteria helps to include a number of different processes that are unique to dense settlements.

3. Cities and sustainability – cities from both the ecological and societal perspective have been presented at the vanguard of emerging conceptual models which include integrated coupled systems that have both human and natural components. A central element of coupled systems is associated with sustainability science and the relative role of resource consumption (food, energy, and water) and environmental transformations – both local and non-local. Several components of the city-sustainability interface are particularly important including resource scarcity, spatial urban development, environmental transitions, and system tipping points. Using this type of model allows researchers to fully integrate the social, economic and environmental urban system analysis into research.

Conclusions

Urban ecologists and urban environmental researchers have not fully engaged in the debate over what is a city. At the same time, however, urban ecosystem studies have a powerful potential to bring back into the debate what cities are, the dimensions of space – size, density, distance, direction, territory and location. Urban ecological studies essentially agree in that they conceptualize and study space as more than a medium in which economic, social, political and historical processes are expressed, but demonstrate that space matters in determining the urban development and the nature of the relationships between different social groups within cities and between individuals and

the environment. We argue, however, that to further enlighten this area we need to pay greater attention to the identification of the city; identifying the socio-economic qualities that differ among cities and make them different from other spaces. In our analyses we should focus on the unique environmental benefits and threats of dense settlement and examine both the differences in the natural features affected by urban activities as well as the social components that define the patterns of these activities.

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Skylines of Hong Kong and Shenzhen, China

Transboundary Urban Systems and Global Environmental Change; The Need for Effective Regional Policy Integration

David Simon

While the interactions between urbanisation and global environmental change (GEC) occur at all geographical scales, research and political attention continue to be focused predominantly at the local, national and global scales. This reflects the political mandates of various governmental or intergovernmental bodies and their associated funding priorities, along with the practicalities of undertaking research.

However, as the recent disruptions to Transatlantic air travel (a vital form of interurban interaction between key components of an increasingly integrated global urban system) caused by the Icelandic volcanic ash clouds reminded us so vividly, environmental change can occur rapidly and unexpectedly, with unpredictable implications for urban systems. Such transboundary urban systems – whether across subnational provincial/state boundaries and/or national borders – have become increasingly important in our globalised world. Yet, analysis of their contributions to GEC and their vulnerabilities and capacities to withstand its effects remains paltry.

Such concerns are central to Theme 4 (Consequences of Interactions within Urban Systems on GEC) of the Urbanization and Global Environmental Chance Project (UGEC) Science Plan (Sánchez-Rodríguez et al. 2005: 39-41). Compared with the other three themes, however, this received the briefest and least clearly focused attention simply because of the paucity of information and available literature at the time of the Plan's drafting. While there has certainly been increasing attention to the issues within this Theme, even five years after publication we know far less about the processes and empirical situations to enable us to answer the key thematic questions. This part of the Plan's text is also vague about geographical scale. With hindsight, it would have been very helpful to indicate more explicitly that the theme refers to urban systems and their components at different scales; moreover, interactions at different scales can intersect and cause cumulative GEC impacts.

Urban systems were a central focus of research and policy attention from the late 1950s to mid-1970s, an era of rapid worldwide economic growth and when environmental concerns first gained prominence. This is true in many parts of the world, including poor, so-called developing countries, where donor-driven aid programmes were rolled out to promote urban development in towns or cities of sizes identified as missing links in supposedly regular urban hierarchy structures. However, during the subsequent recession and "neoliberal turn"

that greatly reduced state capacity for spatial planning in most countries, such concerns faded from view and the generally less than successful interventions were abandoned as costly failures (Simon 1990; Parnell and Simon 2010).

However, ongoing globalization and urban integration, along with environmental concerns and the rising climate change challenge, are once again demanding attention to urban systems in both research and policy terms. Urban-industrial complexes increasingly straddle national borders, often exploiting the locational advantages of different resources, planning, environmental and property development and taxation systems, as well as labour regimes and wage levels in one country, but serving combined markets both within the sprawling conurbation and beyond. Well known examples are Tijuana – San Diego and Cuidad Juarez – San Antonio on the Mexican – US border; Buenos Aires – Montevideo linking Argentina and Uruguay; Geneva – Gex across the Swiss – French border; Shenzhen – Hong Kong, and Johor Bahru – Singapore – Bintan linking Malaysia, Singapore and Indonesia.

However, transnational urban corridors are emerging spontaneously in many other areas, e.g. Greater Ibadan – Lagos – Cotonou – Accra (GILA) linking Nigeria, Benin, Togo and Ghana along the West African coast (see photo), or as a result of concerted investments as part of geographically concentrated spatial development initiatives, such as the Maputo Development Corridor linking Maputo, the Mozambican capital, with the Gauteng region centred on Johannesburg in South Africa. Spontaneous developments such as GILA may have tremendous potential, but are also commonly characterised by a lack of integrated planning, service provision and environmental and labour regulatory control.

The volume of heavy goods traffic on the Badagri freeway linking metropolitan Lagos to the nearby Benin border attests to intense transboundary integration within the GILA region.

Profit-led corporate *laissez-faire* does not optimise social net benefit at any scale. Indeed, in transboundary contexts, the geographies of unco-ordinated production and pollution generation may reflect the uneven opportunities and constraints within constituent countries and subnational administrative units, as explained above. Hence the role of the public authorities becomes increasingly important – and requires real capacity and resourcing rather than a neoliberally emasculated state. When GEC issues are brought into focus, with the longer term nature of many impacts and the nature of mitigation and adaptation actions required, the need to reassert a key role for the public sector is underscored. The only effective strategies for co-ordinated planning and regulation lie in very close alignment of the relevant national policies (extremely difficult to achieve) or through the establishment (with appropriate powers and resourcing) of a supranational authority for the conurbation or corridor. Such initiatives within a single country are often contested but where appropriately established, can prove effective. At the supranational level, the challenges of ceding some aspects of sovereign policy-making and finding adequate common ground among two or more governments with potentially divergent political programmes and legal codes in order to facilitate transboundary co-ordination and functional integration are formidable.

Through encouraging and facilitating research and policy engagement on issues under Theme 4 of its Science Plan, the UGEC Project could play an important role in this respect during the remainder of its current mandate.

Two principal and related challenges to coherent policy exist in relation to regional/continental urban systems. The first is the lack of effective institutional "fit" for the full spatial extent of their evolving dimensions since such systems integrate parts of multiple jurisdictions (state/provincial, national and perhaps also supranational regional) but generally do not coincide with their boundaries. Secondly, most existing regional institutions have not hitherto regarded urbanization and urban systems as falling within their remits, so that no institutional expertise, mechanisms or budgets exist to address them. This situation marks a sharp contrast with transport infrastructure, for instance, where (sub-)continental highway projects and aviation policies are often key transnational priorities.

Climate change policy in leading regional institutions like the European Union is relatively well established but is not specifically urban-oriented and is largely focused on emissions trading schemes as the favoured transboundary mechanism. By contrast, many such regional bodies in poorer parts of the world have only recently begun to articulate nascent climate/global environmental policies and to formulate programmes based on them for their respective regions. In one sense, being latecomers may actually prove beneficial in permitting the establishment of appropriate capacity to address urban systems and climate/global environmental change in an integrated and coherent manner – surely a prerequisite for tackling poverty and promoting appropriate development sustainably.

In many cases, this will require significant reorientation of current institutional mandates and structures in order to establish an explicit urban focus and capacity. Particularly where institutional secretariats are small and funding severely constrained, this will not be possible without an explicit steer from the member governments that provide such institutions with authority and resources. This may be difficult to achieve under current financially straitened conditions but also because, in poorer countries where urban populations remain in the minority or have only recently become the majority, political leaders often still draw their support from predominantly rural constituencies and may have ambivalent attitudes to urbanism.

Modern light rail trolley in Buenos Aires, Argentina

Under such circumstances, addressing the GEC dimensions of transboundary urbanisation is more likely to be feasible in the short to medium term through climate change programmes and facilities that already exist or are being established. However, even here and for much the same reason (lack of urban mandate), there is often no specific urban focus at present.

For instance, the two principal regional integration institutions covering southern and east Africa with partially overlapping memberships, the Southern African Development Community (SADC) and Common Market for Eastern and Southern Africa (COMESA), have both introduced climate change programmes since 2007. This was achieved as part of a Norwegian-funded initiative. Both organisations' initial efforts have been commendable but remain in an early stage of evolution and hampered by broad mandates and just a handful of staff each. SADC undertook an impressive analysis of the relationships between poverty and climate change as a basis for defining priorities, while COMESA has adopted a Climate Change Initiative with eight sectoral or functional foci.

However, in neither case is there any systematic geographical disaggregation except by agro-ecological zone for certain agricultural and livestock policies. In particular, no distinctions are made between rural, peri-urban and urban areas, with the result that incipient policies cannot at present be tailored on this basis. Nevertheless, since the climate change frameworks do now exist and the newly established units may still be amenable, this appears the more appropriate immediate route through which to press the urgent case for adopting GEC policies appropriate to transboundary urbanisation, while also seeking to have regional institutions recognise the importance of addressing urbanization processes more comprehensively in their own right.

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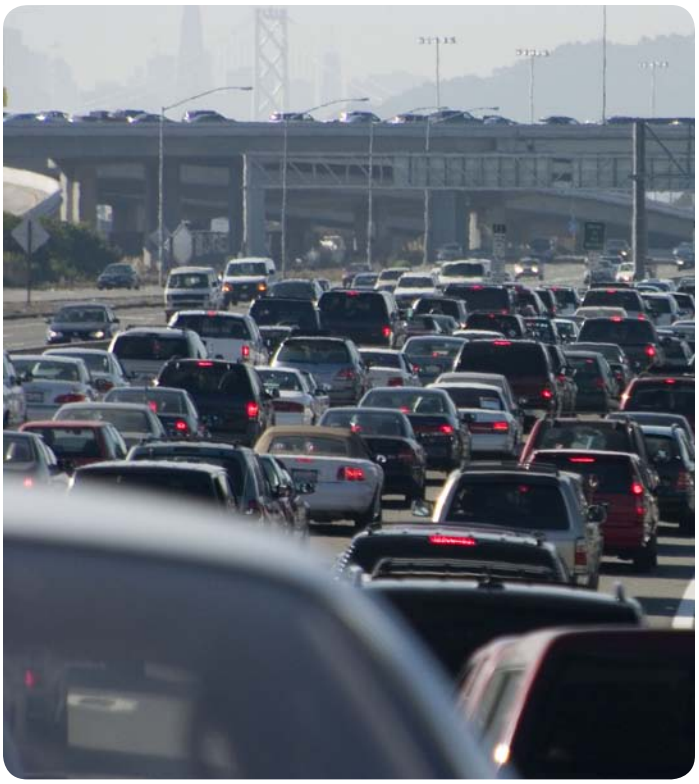
Singapore skyline in the twilight hours

Governing Climate Change in the City

Harriet Bulkeley

As the potential vulnerability of urban centres to the effects of climate change and their contribution to rising levels of atmospheric greenhouse gas emissions has been recognised, a growing body of literature has sought to understand how climate change is being governed in the city (Bulkeley 2010). Contributing to the wider field of global environmental governance, concerned with understanding climate governance "beyond" the international regime, this literature has focused on the actors and institutions involved in urban responses. Within this framework, the success, or otherwise, of urban climate governance, is regarded as either a matter of institutional capacity – for example, concerning the jurisdictional remit or resources of municipal authorities – or as shaped by political factors – for example, the opportunities for political leadership or the degree to which addressing climate change fits with other social and economic concerns in the city (Bai 2007; Betsill and Bulkeley 2007; Bulkeley et al. 2009; Romero Lankao 2007; Schreurs 2008).

This work has been significant in three key respects. First, it has succeeded in challenging the notion that "global" (environmental) politics is confined to the international political arena. The use and development of multi-level governance perspectives within this field has been critical to opening up the terrain of global environmental governance, demonstrating the ways in which international, national, regional and local climate politics interact, as well as identifying the emergence of new horizontal governance arenas which work across and within territorially-based levels of political organisation (Betsill and Bulkeley 2006; Bulkeley and Kern 2006; Corfee-Morlot et al. 2009; Davies 2006; Gore and Robinson 2009; Kern and Bulkeley 2009; Monni and Raes 2008; Puppim de Oliveira 2009). Second, it has demonstrated the critical capacity challenges – in terms of knowledge, resources, institutional fragmentation, and more – facing urban authorities as they seek to respond to the twin challenges of adaptation and mitigation (Holgate 2007; Parnell et al. 2007; Romero Lankao 2007; Satterthwaite et al. 2008). Third, it has revealed that behind the seemingly "win win" discourses of economic, social and environmental gain, addressing climate change in the city provokes fundamental



political tensions over how and for whom environmental protection and economic development should be pursued (Bulkeley and Betsill 2003; Granberg and Elander 2007; Huq et al. 2007).

Despite these important insights, work in this field has been limited in two main regards. First, attention has focused primarily on mitigation and the cities where research has been conducted have either been "pioneers" or "global" cities, restricting what we know about how climate change is being addressed in ordinary cities, particularly in the global south. Second, with its roots in global governance and the study of global environmental change, much of this literature has failed to engage with concepts of governing that move beyond an institutional analysis. While many commentators have raised concerns about the limited empirical reach of urban climate governance work, it is this latter, conceptual limitation, which may be more significant in shaping both what we know, and how we know, about cities responding to climate change. In order to develop our research in this area, I argue, we need to engage with alternative concepts of power and politics which, in turn, raise questions of the ways in which the very 'stuff' with which climate governance is concerned – infrastructure networks, energy, loft insulation, electric cars and so on – come to matter in governing the city. In the rest of this short review, I outline these challenges and highlight some emerging work in these fields which could provide new impetus for this research agenda.

Towards a new urban politics of climate change

Although the politics of urban climate governance has been central to work in this field, it remains, for the most part, curiously under-theorised. There are, I think, two aspects to this problem. First, essential categorisations, and perhaps most prominently the idea of the state, remain taken for granted. Reflecting the wider literature on global environmental governance, state and non-state actors are defined in institutional terms, regarded as more-or-less coherent entities and confined to separate spheres of the social world (Painter 2006). As a result, most authors have regarded multi-level governance as the stage upon which the drama of urban responses to climate change are played out. There has been considerably less attention given to the possibility, central to mainstream urban studies, that the urban governance of climate change may be a key site in the reconfiguration of (state-based) political authority – a means through which the division of powers between levels of government, and between state and non-state actors is forged and contested. Research in this vein is emerging. In their discussion of the climate policies developed by two cities in Sweden, Sundsvall and Växjö, Gustavsson et al. (2009: 70) argue that a "rescaling of statehood" (Brenner 2004) is taking place such that "climate networks and other networks are relatively self-governing, with collective actors challenging the territorially bounded, vertical, nature of central - local government relations." While et al. (2010) make a stronger claim for the reworking of the state and its implications for urban and regional governance through the processes of "eco-state restructuring" emerging around the problematic of "carbon control". This, they suggest, is giving rise to a "distinctive political economy" given that discourses of mitigating climate change both "open up, and necessitate an extension of, state intervention in the spheres of production and consumption. Controlling carbon emissions might be seen as a problem and an opportunity for advanced liberal states" (While et al. 2010: 82; see also Hodson and Marvin 2009). While the validity of such claims requires further empirical work in different contexts, this research challenges us to more critically engage with how, and why, governing climate change in the city is becoming a strategic issue through which the boundary between state/non-state, public/private, is being forged.

A second, and intimately related issue, concerns the basis upon which the "politics" of urban climate governance is conceived. In essence, this is structured by "an ingrained idea of power as an instrument of domination, a capacity of some resourceful mix"

(Allen 2008: XX); of the "power over" some by others (Barnett and Duvall 2005: 2-3). In essence, the use of power by one set of actors is regarded as constrained by the power of others (as manifest, depending on the frameworks employed, in terms of resources and/or discourses). This leads to analysis which points to the ways in which "higher" levels of the state – the region, national government – can limit local action, and also to the conclusion that "an increase in the power of non-state actors is ipso facto defined as a simultaneous reduction on state power and authority" (Sending and Neumann 2006: 652). In their study of the development of urban climate policy in Portland, Oregon, Rutland and Aylett (2008) argue that understanding the "work" of policy requires a different conceptualisation of power and of governance, one based on theories of governmentality and actor-networks. Using this framework, they provide a detailed and compelling account of the ways in which interests were aligned and a diverse collection of actors were brought into an assemblage through which greenhouse emissions came to be governed locally. As they explain, in the process of the development of policy "targets and tactics were applied only to elements of energy consumption that could be influenced in an acceptable way by the municipal government. Energy used in flights to and from Portland International Airport, for instance, was excluded. Also excluded were the significant amounts of energy used in importing and exporting commodities, and the energy actually embodied in commodities" (Rutland and Aylett 2008: 636). In effect, by conceiving of power as an immanent (Allen 2004: 65), it is possible to examine how the process of making policy also constitutes what the object to be governed should be, with important implications in terms of our understanding of how climate change is addressed, and whose interests are served.

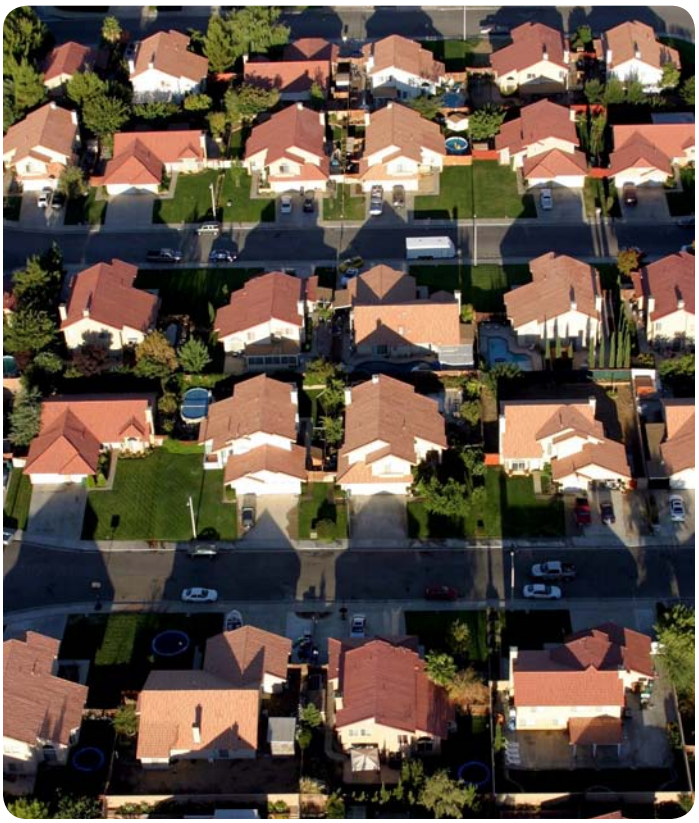
The stuff of governing

Opening up the ways in which power and politics are conceived in urban climate governance also draws our attention to another, fundamental, issue – how, where and by whom is climate change conducted in the city? Work in the field of urban climate governance has been important in drawing our attention to the myriad of actors and institutions – from environmental campaign groups, community-based organisations, policy entrepreneurs, corporate organisations, donors, charitable trusts and so on – who are engaging with governing climate change in the city beyond the (local) state. For the most part, however, the substance of policy, the "stuff" with which the governing of climate change is concerned – notably infrastructure networks, energy-consuming artifacts, drainage systems, pavements, insulation and so on – have been ignored, a backdrop upon which policy is played out. As a consequence, such things are seen as either immaterial to climate governance, as inherently malleable – amenable to change once the right policy framework has been devised – or as posing an insurmountable barrier to policy implementation. In each case, the ways in which particular networks, materials and artifacts come to matter in governing climate change, and in particular in how the "object" of climate governance – be in energy efficiency, transportation, coastal defense and so on – remains hidden from view.

As with the discussion of power and politics above, this partial view of the landscape of urban governance results from a focus on actors and institutions, and will inevitably be a matter for the theoretical preferences of individual researchers. However, in the urban arena, ignoring the materiality of climate governance effectively closes down engagement with two bodies of work which could provide significant insights into why and how the examples of cases where there is evidence that urban responses are moving beyond rhetorical commitments into effective action are so limited.

First, work in the tradition of what has become known as "splintering urbanism" (Graham and Marvin 2001) has demonstrated the important ways in which urban infrastructure networks – energy, water, waste, sanitation – are being reconfigured through the processes of neoliberalisation, privatisation and decentralisation, "aggravating urban (social/spatial) inequalities by emerging patterns of network provision, access, and use" (Monstadt 2009: 11). Given their central role in shaping the potential for urban climate governance, the current lacking engagement with the governing of such infrastructures, and the ways in which they are being reconfigured, is a major omission in this field (Monstadt 2009).

Second, an emerging body of work loosely known as "urban political ecology" also provides a means for a more explicit engagement with the ways in which the materiality of cities is essential to their politics. Eschewing traditional divisions between nature and culture, scholars in this field point to urban "metabolism" as the means through which governing is produced. In this reading, urban metabolism is not a merely material (and energetic) process: it also involves exchange of power and meanings across a network of flows beyond the biophysical exchange. In sum, metabolic circulation is "the socially mediated process of environmental, including technological, transformation and trans-configuration, through which all manner of 'agents' are mobilised, attached, collectivised, and networked" (Swyngedouw 2006).



Rather than focusing our analysis purely on institutions and actors, work in these two traditions suggests that in order to understand why, how, and importantly, where, the governing of climate change is taking place, we need to attend to the ways in which technologies and artifacts are configured, circulated and excluded in order to delimit the arena of climate politics. This, in turn, suggests that we may need to move beyond the study of policies, plans and discourses in order to understand the "whereabouts" of climate governance – to examine the projects, technologies and developments that are being crystallised in the name of attending to climate change (Bulkeley and Castan Broto 2010).

Future agendas

There is then, more to do. As I suggested at the beginning of this piece, our picture of urban climate governance is currently limited by the places and issues with which the research community has engaged and there is a pressing need to engage with ordinary cities and in the urban areas of the global south. However, as I have argued here, perhaps the more fundamental challenge concerns the ways in which we conceptualise the urban, the political, and the state. While our work has, to date, been fundamentally driven by core concepts within the global governance tradition – primarily of architecture and of agency – there are a range of other conceptual perspectives which may provide greater traction on the subject matter with which we are concerned. In turn, drawing on alternative theories of power and politics, and conceiving of the urban as fundamentally socio-natural and socio-technical, may enable us to offer new insights into fundamental questions of global governance, including, for example, how governing is accomplished and the ways in which authority is manifest. In so doing, we can hope to learn much more about how, by and for whom, climate change is being governed in the city, and its consequences for social and environmental justice.

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View from Mt. Kilimanjaro Uhuru Peak

Urban Vulnerabilities and Adaptation in Low Income Countries; Perspectives for Future Research in Africa

Shuaib Lwasa

Climate change is now recognized as a critical dimension of global environmental change and is climbing higher up onto global and national agendas (Tirpak et al. 2010; Clements 2010; Conway 2009). The Intergovernmental Panel on Climate Change Fourth Assessment Report (AR4) identifies Africa as a vulnerable region and although it historically and presently is a small contributor of greenhouse gas emissions, the continent is disproportionately affected by climate change impacts (IPCC 2007; Harmeling 2010). Reports also reveal that vulnerability to climate change in Africa is increasing due to systemic challenges that encompass the social, economic, political and environmental spheres. These challenges hamper steadfast preparedness necessary for confronting the effects of climate change.

While it is well known that rural Africa is highly vulnerable, new knowledge is emerging on the vulnerability of African urban areas (Junior and Spaliviero 2009; UN-Habitat 2009). These cities face a variety of serious climate impacts and the future trends, severity and magnitude of these impacts are uncertain (IPCC 2007). For example, coastal cities are highly vulnerable to the climate impacts of sea level rise and storm surges, while inland cities face impacts of flooding, droughts and extreme climatic events. Mountainous cities are threatened by new diseases due to warming that has extended vector ranges, and by threats of water scarcity partly created by the melting of glaciers or the degradation of catchments (Junior and Spaliviero 2009; Lwasa et al. 2009a; Thiam et al. 2009).

Furthermore, Africa is the fastest urbanizing region in the world and it is estimated that by 2030, half of its population will live in urban areas (UNFPA 2007). Although the literature has described the urbanization process in Africa as "pseudo-urbanization", where cities form without the needed infrastructure to support them, evidence suggests that urbanization is progressing in countries where economic growth rates have remained steadily high (IBRD 2009). Several drivers are responsible for urbanization including population dynamics, economic growth, legislative designation, and increasing densities in rural trading centers. Most notable are the mega cities of Lagos, Cairo and Kinshasa, which are expanding ever further (UN-Habitat and ECA 2008). UN-Habitat also notes that at the continental scale,

urban-regions are emerging along the Mediterranean coastline, South African coastline, West African coastline and within inland urban areas of Eastern Africa. Given the existing trends and pathways of urban development, urbanization is exposing more people to climate change impacts and thus, increases urban vulnerabilities. The multi-dimensional complexities of urban form, urbanization and urban governance in Africa have left city authorities and governments unprepared for climate change.

Whereas there is evidence of adaptation and a movement towards sustainability in African cities, fast paced urbanization and its linkages to climate change will remain major research issues in the coming decades (Bicknell, Dodman and Satterthwaite 2009; Carmin 2009). In addition to being the most vulnerable region, Africa is entangled in a complex web of development challenges to which climate change adds a whole new dimension. Although urbanization presents opportunities in Sub-Saharan African countries, the challenges for sustainable urban development are overwhelming. In addition, these challenges pose sustainability concerns in social, economic, environmental and institutional contexts which require well designed impact pathways that are climate responsive for urban development. In this article, current urbanization and global environmental change (UGEC) research in Africa is analyzed in the context of the conceptual framework laid out in the Urbanization and Global Environmental Change Project Science Plan (Sánchez-Rodríguez et al. 2005). Drawing from UGEC research knowledge, the article also points to gaps that must be addressed in the future to better understand the processes and linkages between urban functionality, climate change and requirements for adaptation.

Emerging knowledge

The reality of dealing with the effects of climate change on a global level is now very clear. Cities have been identified as both contributing and being vulnerable to climate change and as observed by the United Nations Environment Programme (UNEP), Africa is the most vulnerable region due to its technological, managerial, administrative and financial unpreparedness (UNEP 2007). UN-Habitat (2009) notes that the effects of climate change are exacerbating the already grim environmental, social and economic problems, increasing poverty and putting the urban poor at the greatest risk (Bicknell, Dodman and Satterthwaite 2009). Current UGEC research in Africa shows considerable progress in generating the required knowledge about how cities contribute to and are affected by climate change (Denton and O'Neil 2008). Research also indicates, though on a limited scale, how cities are responding to climate change to reduce urban vulnerabilities in Africa (Lwasa et al. 2009b; Moser 2009; Olorunfemi 2009). Urban vulnerabilities are manifested in areas of water resources, health, housing, energy, food security, functional transport infrastructure, environmental services and economic productivity (IPCC 2007). Efforts across the continent are underway to raise awareness, develop tools and build capacity for municipalities and intensification of adaptation activities in response to climate change. Early adapter cities are also providing leadership in developing scalable adaptation measures which can be implemented at the community level and to the city level through demonstrative projects for sustainable urban development (Oxfam 2007).

Cutting-edge research

Urban vulnerability assessments have been completed at the levels of national and city, or city-region scales (UN-Habitat 2010). Through the use of various analytical frameworks drawn from the conceptual framework in the UGEC Science Plan, demographic, health, environmental and socio-economic data has been integrated and analyzed in innovative ways to facilitate understanding of the interactions between urban systems and biophysical processes (Sánchez-Rodríguez et al. 2005). Assessments have covered the subcontinent-regional scale, national and sub-national regional scale and city and neighborhood scales. The analysis of urban vulnerabilities draws largely on an analytical framework of exposure-to-risk factors to mediating factors to outcomes of climate change impacts. This model is supporting knowledge generation on multi-scaled differential urban vulnerabilities in Africa and on how to adapt to climate impacts (Waibel 2008). A key complementary research and analytical framework lies in the utilization of participatory methods that have underscored the importance of cities as social processes igniting engagement between scholars, civil society organizations, policy makers and academics in search of scalable adaptation measures (Lwasa and Kadilo 2010; Pennington 2008).

Taking stock and looking into the future

Africa is characterized by a variety of climates, but the most critical climate changes include increased/reduced precipitation, increasing temperatures and seasonal changes that translate into droughts, floods, extended dry-spells, tropical storms, and cold and heat waves (Conway 2009; IPCC 2007. McSweeney, New and Lizcano 2006-2010). The warming of Africa causes

the melting of the few remaining glaciers and snow caps of Kilimanjaro and Ruwenzori. The El Nino Southern Oscillation phenomena associated with the migration of the Intertropical Convergence Zone largely drives the changes observed in much of Africa. These climatic changes have implications on urban vulnerabilities. However, while there are several scenarios of the observed and predicted changes in climate, there are gaps in the knowledge on vulnerability of urban areas that must be addressed further by UGEC research (Peirce and Johnson 2008).

Coastal cities are facing and will continue to be threatened by storm surges and rising sea levels. Understanding climate proofing needs, adaptation and the reduction of risk associated with these storm surges will be critical issues in the future of UGEC research. Inland cities, on the other hand, are faced with impacts of flooding, droughts, sand storms, scarcity of water, biodiversity loss and heat or cold waves (Padoch et al. 2008). Future research will have to address the need for knowledge on needed adaptation measures at various scales in different cities, despite local differences. Mountainous and highland cities are faced with warming of temperatures, water scarcity, ice melting and biodiversity loss. There is a dearth of knowledge on adaptation to the impacts in these cities. In all of these cases, future research must address the ways in which social and economic systems will need to be adjusted for climate adaptation (Lwasa and Kadilo 2010; Pennington 2008). In addition, institutional adaptation and readiness is an overarching requirement about which limited knowledge exists. Thus, coupling adaptation to climate change and development is a very critical area to which existing wisdom does not provide immediate answers. Advances in adaptation research reveal that experiential learning provides a robust model to galvanize knowledge on how to respond to climate change impacts (Satterthwaite et al. 2007 and Smit et al. 2001). The learning-by-doing model has the potential of facilitating new knowledge in a manner that has up until now, been under used.

Cairo, Egypt

The importance of knowledge sharing

Knowledge remains a key ingredient in the process of responding to climate change. It is well recognized that a wealth of climate change knowledge exists, but does not offer a complete understanding of the dynamic nature of impacts. Likewise, knowledge from the experiences of early adapters exists, but this is not widely disseminated, necessitating innovative ways of enabling information flow for the up scaling and out scaling of adaptation innovations. Thus, information sharing will be an important issue among researchers and between researchers and stakeholders on issues of adaptation to climate change (UNDP 2007). Future UGEC research priorities will have to include the translation and sharing of information and it will be critical for the research community to engage with other stakeholders. Information sharing networks are vital to enable the flow of such knowledge and a model for exchange is emerging at various scales from Local Urban Knowledge Arenas (LUKAS) to Global Urban Knowledge Arenas, as advanced by UN-Habitat. Through these local to global networks, flow and exchange of information is likely to be stimulated, driving urban adaptation by providing platforms for knowledge generation and better understanding of climate change adaptation. As adaptation will be a top priority for climate change programmes in Africa and given the existing development challenges, community-based adaptations will be very critical in the future research agenda. Drawing from the foregoing discussion, there are many knowledge gaps. Some of the most critical areas for future research in Africa include urban governance and preparedness for climate change; adaption through spatial planning, energy efficient housing and transportation, conservation of urban natural resources, urban greening, local economic development and integration of the "emerging" informal sector into the urban economy and planning for low-carbon economies taking into account "green" technologies with a potential to reduce poverty

(Went, Newman, and James 2008). Addressing these critical issues will be important for a fuller understanding of how Africa can better respond to climate change.

Conclusion

Climate change adaptation will be important for African cities. The impacts of climate change are neither disputable nor can be underestimated, due to increasing evidence of climate change induced problems in many African cities. Adaptation of urban areas to climate change is context specific and though good practices are emerging, additional knowledge on the workability of these adaptations is needed. A key requirement for urban vulnerability research is the engagement with stakeholders including policy makers and communities. This will be an important vehicle for scaling up climate change adaptation. The current urban development patterns in Africa may arguably have little flexibility to change, but integrative strategies are needed to support early adapter urban communities and enhance resilience to climate change.

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West Coast town in USA

Remote Sensing of Urban Areas for Climate Change Science

Karen C. Seto & Peter Christensen

The spatial organization of urban areas – the footprint and height of buildings, the width and length of streets, where we live versus where we work, the walkability and scale of a neighborhood, the relative proximity of urban amenities, the type and diversity of urban green space – affects urban energy use and greenhouse gas emissions. In addition, urban land use, urban design, and urban form affect the carbon cycle through the expansion of urban areas and the loss of carbon stocks. Given anticipated trends in urban growth, an expected increase in global urban population of 2.7 billion by 2050 (UN Population Division 2010), there are enormous opportunities to shape the built environment and urban land use practices. At the same time, it is clear that urban areas and urban spatial planning will need to be components of climate change mitigation and adaptation. Specifically, we need to decompose the "urban black box" and better understand the links between the spatiality of urban areas, energy use and emissions, and opportunities for climate change mitigation.

Most of the current discussions about urban carbon emissions mitigation focus on three components: energy efficiency, energy conservation, and carbon sinks. For example, increasing fuel efficiency for 2 billion cars from 30 to 60 mpg could save 14 Giga tonnes Carbon (GtC) per year, equivalent to one "stabilization wedge" (Pacala and Socolow 2004). The same amount of carbon emissions could be saved by decreasing car travel by half for 2 billion 30 mpg cars, from 10,000 to 5,000 miles per year (Pacala and Socolow 2004). "Green buildings" could reduce energy consumption through building design, siting, and materials use (Lockwood 2006). Urban vegetation can also play an important role in carbon sequestration and emissions. Urban trees in the conterminous United States sequester approximately 22.8 million tonnes of Carbon (tC) per year (Nowak and Crane 2002), and there is growing interest in understanding how urban tree cover mitigates the urban heat island effect. There is also potential for turfgrass, or lawn, to be a net carbon sink depending on how they are managed with fertilizers, irrigation, mowing and leaf-blowing (Townsend-Small and Czimczik 2010a, 2010b). Although the measures required to achieve these goals may be difficult politically,

in principle we know the range of energy and emissions savings if we drove less, drove in more efficient cars, and lived and worked in more energy efficient buildings.

A larger challenge facing the urbanization and global environmental change community is to understand the relationships between urban form and function, and energy use and carbon emissions. Missing from the current literature are scientific assessments that decompose urban areas into different spatial patterns and evaluates their impacts on greenhouse gas emissions. Yet, these types of analyses are urgently needed by urban planners and local decision-makers who are recognizing that planning and zoning at the local level have affects on mobility and transportation choices, energy consumption, and ultimately, climate change. Around the world, more than 100 cities have established local climate change action plans. Most of these plans set targets for reducing greenhouse gas emissions by a future date. For example, Sydney, Australia, has set a greenhouse gas emissions target for 2030 that is 70 percent below the 2006 levels (City of Sydney 2007). Equally ambitious, the Paris Climate Plan seeks to reduce greenhouse gas emissions by 75 percent below the 2004 levels by 2050 (City of Paris 2007). Across the plans, there is a commonality of a multi-sector, multi-scale approach to reaching reduction targets: improved transportation options, renewable and green energy production, more efficient buildings, reducing waste and pollution, mass-transit fleets with zero emissions, increasing urban vegetation cover, etc. What is missing from most plans is a clear link between urban land-use patterns beyond the individual parcel or building scale, and energy use or emissions.

Our understanding of the relationship between urban areas and the carbon cycle has advanced significantly in the last two decades. Empirical studies have quantified the impact of urban areas on two primary components of the carbon cycle: the loss of carbon stocks through expansion of urban areas and the increase in carbon emissions through energy use. Key findings conclude that:

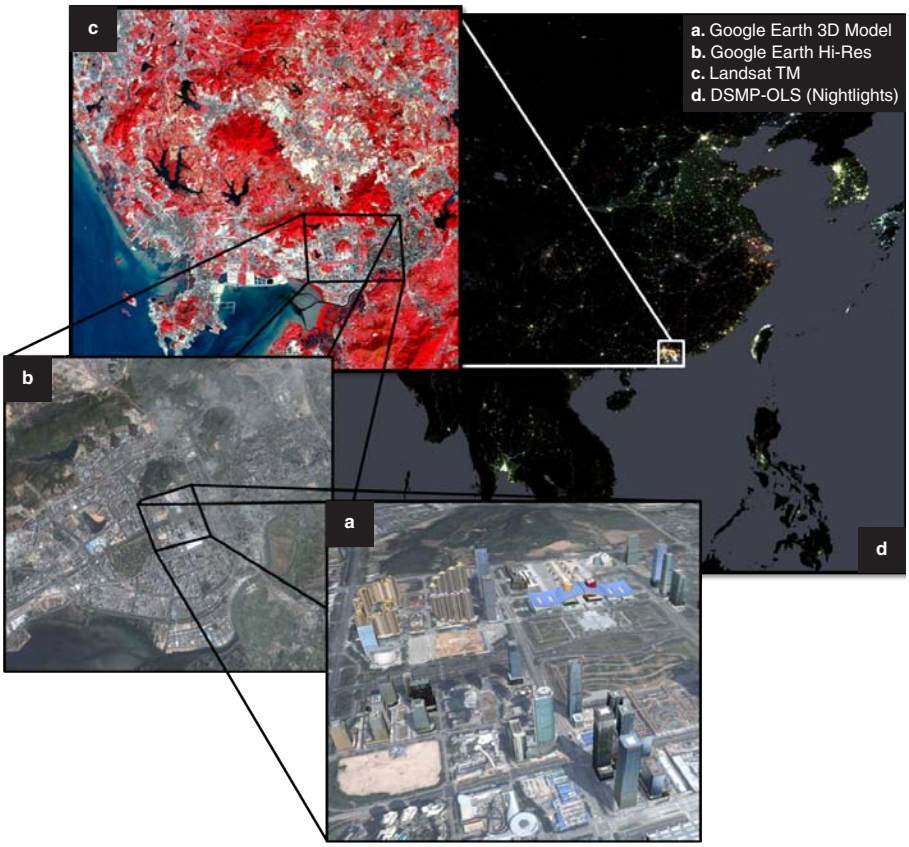
- The spatial pattern of urban land use, urban growth, and urban form affect transportation choices, energy use, and carbon emissions (NRC 2009; Marshall 2008).
- There is significant variation in urban carbon emissions per capita, but on average, urban carbon emissions per capita are lower than national per capita averages (Dodman 2009).
- Urban land-use affects adjacent forest soil carbon pools even in stands not directly affected by urban land expansion (Pouyat et al. 2001).
- Understanding the factors that determine the trajectory of sinks in urban areas is a key research question for the coming decades (Pataki et al. 2006).

However, very little is known about urban land use dynamics across a typology of urban areas – especially small and medium-sized cities – around the world, and their impacts on vegetation and carbon stocks, energy use, and emissions. Consequently, local planners and decision-makers lack scientific information about the potential climate impacts of different urban land-use patterns, urban growth scenarios, and the design and development of urban areas across multiple spatial scales.

Although there has been much progress in the use of remote sensing to study urban areas, urban growth, urban ecology and urban climate, there are still significant untapped opportunities in linking urban remote sensing to climate change science and research on greenhouse gas emissions. For example, the research community's efforts at monitoring urban expansion with remote sensing have been focused primarily at large cities, but it is the smaller cities that will be expanding the greatest, where carbon stocks are most vulnerable, and where there are the greatest opportunities to shape urban form, urban infrastructure, and urban land-use patterns. Furthermore, satellite remote sensing offers opportunities to expand the urban lens beyond the extent of a

Small town, USA

Figure 1 | Multi-scaled analysis of the urban environment



single city, linking global patterns of urbanization to the study of global environmental change (see Figure 1).

Remote sensing offers unique perspectives to study the relationship between the urban system and climate change because it is: 1) inherently geographic and provides a synoptic view of the landscape; and 2) available at multiple spatial grains and spatial extent, therefore able to provide detailed information from an individual building to regional and continental patterns of urbanization. Here we identify linkages between the urban system and climate change, and the opportunities for remote sensing to increase our understanding of these relationships.

1. Comprehensive imaging of the built environment. In the United States, the transportation sector accounts for one-quarter of the country's total energy consumption, and the residential and commercial sectors combined account for 20 percent. A more comprehensive remote sensing effort to detect all components of the built environment, including transportation networks (railroads, major highways, arterial roads), building types (commercial, industrial, residential), and 3-dimensional structure of buildings (height and footprint) would allow for greater understanding of the relationship between urban form, transportation choices, mobility patterns, energy use, and carbon emissions.

2**. Multi-scale urban form dynamics beyond the pixel.** Urban form impacts building energy use, transportation patterns, embodied energy, and heat island dynamics. While most conventional urban remote sensing analysis focuses on changes within individual pixels, a more comprehensive analysis of urban form will require increasing focus on the spatial configuration of urban pixels. The physical organization of urban areas is central to energy use, and this is where remote sensing can provide a significant contribution. This will require new thinking about classification, accuracy assessment, and modeling.

3. Urban climate change mitigation and adaptation planning. Currently, urban policymakers and cities are at the forefront of developing climate change adaptation and mitigation policies, with more than 100 cities worldwide developing climate adaptation plans and over 1,000 U.S. mayors signing climate change protection agreements. However, a majority of these efforts are not science-based or science-informed, and there is

much opportunity for remote sensing science to contribute to and help develop science-based mitigation and adaptation policies at the urban scale.

4. Distinguishing between urban carbon sink and source dynamics. While the use of remote sensing methods in carbon cycle science has historically focused on sequestration dynamics, satellite data also provides input to models of urban carbon emissions. Satellite data are currently being utilized to examine atmospheric pollutants within and around urban areas. In addition, there are opportunities to combine the study of urban land cover dynamics with analysis of key emissions factors such as infrastructure construction, building energy operations, commute patterns and locations of residence and employment. The integration of research on urban land cover change with studies of emissions is particularly important, since "urban energy use/emissions" has historically been defined exclusively as a population phenomenon, which ignores the importance of how humans and infrastructure are configured geographically.

5. Scale: understanding urban contributions to energy use and carbon dynamics from the individual building, to block, neighborhood, city, region, nation, and ultimately to the global system of urban centers. At each scale, different factors become important to determining the global climate problem and appropriate solutions to global climate change. By integrating research across scales, scientists can help to break down the divide between local planning, regional assessment, national policy, and international negotiation.

6. Understanding the impacts of climate change on urban areas. Urban infrastructure is particularly vulnerable to extreme climate events such as wind, snow, ice storms, hurricanes and heat waves. This will result in a growing exposure to risk and changing risk profile for those who live in urban areas that can be quantified with remote sensing. By combining satellite-derived risk analysis with geographical models of climate-induced migration, scientists can also examine regional and global patterns of urban climate adaptation.

7. Incorporating the third dimension. Urban settlements either build out or build up. Thus far, the vertical dimension of urban areas has not been widely analyzed with remote sensing. Adding this third dimension will provide a critical component of urban form and a clearer understanding of the relationships between density, mobility, and efficiency.

8. Change over time. With more than 30 years of the Landsat data archive, we can measure historical urban form and evaluate the role of government policies and incentives in shaping carbon intensive land uses. These analyses can be used to understand historical drivers and to simulate potential patterns of urban expansion and changes in energy use and carbon stocks.

Given the vast and growing inventory of remote sensing data available from government and industry sources, there is an exciting opportunity to develop a more comprehensive understanding of urban systems and their relationships with energy use, emissions, and carbon dynamics. Perhaps even more important, there is an urgent need to further our understanding so that remote sensing can be a relevant and timely tool to help inform policy-making.

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New York City, New York, USA

Towards a New Science and Practice of Adaptation to Climate Change in Urban Areas

Michail Fragkias

In the last five years we have observed an increasing number of cities around the world initiating responses to climate change through (combined) mitigation and adaptation actions and other initiatives (Sanchez-Rodriguez 2008). Given the levels of the expected irreversible climate change in the next decades, adaptation action is not optional (Solomon et al. 2009). Adaptation planning and action are critical for the well-being of future generations of urban dwellers. The diversity of the ongoing initiatives allows us an early opportunity to begin utilizing the richness of research and new knowledge they have provided. Initiatives such as the Urbanization and Global Environmental Change (UGEC) project have begun a cross-regional synthesis of our knowledge on how cities have begun to respond, fail to respond, or could better respond to climate change. Nonetheless, a major challenge for scientists and practitioners remains: How do we best analyze and synthesize the growing number of case studies, in order to better understand the complexities of the responses? Taking a broader perspective of the issue, in this short essay, I attempt to identify some of the critical elements of current work that constitute the foundation for a new science and practice of adaptation to climate change for urban areas and offer a few potential future directions.

Presently...

A significant amount of attention has been placed thus far on understanding the diversity of institutional and technological drivers of current responses to climate change; different actors and institutions (in public, private, social, informal sectors, and international organizations) and their roles in the development of responses to climate change in urban areas; the deficiencies and resistance of institutions to respond to climate change; the windows of opportunities to overcome them; and how cooperation/collaboration between actors could effectively establish better measures, solutions, and responses to climate change (Rosenszweig and Solecki 2010). Others have begun to

synthesize evidence from worldwide case cities that have already received attention (both from less developed and more developed countries), and provide insights on both opportunities and constraints for complementing climate change mitigation with adaptation strategies in the context of development (Heinrichs et al. 2009). It is clear that there is substantial knowledge from existing work upon which a new science on adaptation to climate change can build.

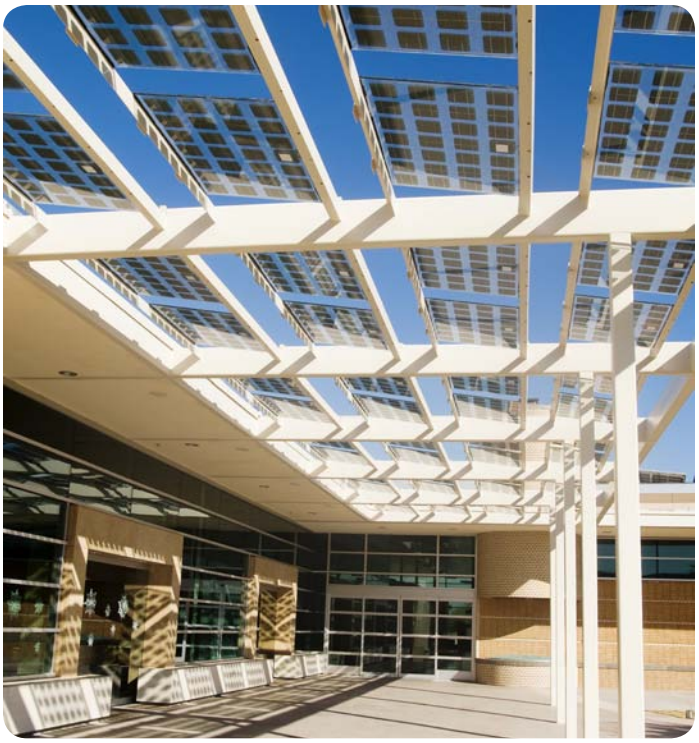
The scientific dialogue has recently brought into focus several issues of particular interest. The first research projects on the topic have begun exploring the strengths and weaknesses of current responses to climate change, especially with respect to the diversity of the actors, groups or organizations who are involved in (or leading) the responses. Main concerns revolve around questions of coordination (horizontal and vertical), distribution of authority (fiscal, political, administrative), the specific role of local (community) actors and the interactions across scales with regional and national actors or institutions. With regard to urban areas that have not initiated responses, researchers have explored whether there are common obstacles that prevent cities from responding to climate change, such as policy-making inertia, policy mismatches across temporal and spatial scales, resistance from special interest groups, capacity, or high levels of uncertainty (Heinrichs et al. 2009).

A dimension that has attracted a significant amount of attention is that of the role of institutions and institutional change, and in particular, general governance arrangements, practical frameworks and specific mechanisms as drivers of the responses. Different policies have been designed to implement mitigation/adaptation strategies and a variety of instruments (for example, in urban planning, housing policies and building ordinances, and transportation planning) are used to incorporate climate change concerns. However, in many cases, local policies and instruments are not forward-looking, flexible and adaptable. Major concerns on this issue include the adaptability of local institutions to the challenge of climate change, the prioritization of institutional responses at different administrative levels, and the level of compatibility and coherence of mitigation and adaptation actions with the local urban development agenda. While there are important avenues for further mainstreaming the climate change agenda and integration with existing policies and instruments, climate change itself has been viewed as an opportunity for institutional change, as potential solutions cut through the "silos" of academic disciplinary knowledge and practitioner uni-sectoral approaches.

The above research and on-the-ground practice are still confronted with knowledge gaps on several fronts: First, in the understanding of how responses to climate change in cities can work more efficiently and effectively and what further research is needed on this issue. In particular, literature on what knowledge policymakers and practitioners require from scientists and how this knowledge can best be integrated with policy agendas, are still not well integrated. Secondly, the so-called gray literature (governmental and NGO reports) on the topic has already produced a significant number of suggestions in the form of "good practices"; but it is still a question whether those be replicated widely and globally. Uncertainty plagues the degree to which different types of policy-relevant knowledge produced for specific locals can be generalized. Very importantly, it is unclear how the knowledge generated needs to be communicated and translated for the capacity building of local organizations and how it could translate into national and regional assistance strategies. Thirdly, researchers have not yet adequately addressed the steps that need to be taken to foster urban sustainability through responses to a wide array of expected climate change impacts (Seto and Shepherd 2009).

Future directions...

There are several emerging areas towards which the science of adaptation needs to direct advancements. It is very important for scientists to refine widely used concepts such as vulnerability, risk, resilience, adaptive capacity and provide meaningful definitions in order to strengthen the foundations of a new science of adaptation in cities. We need to understand the clear connections of a new science and practice of adaptation to climate change and sustainability science or resilience. Scientists also need to sharpen their tools; in particular, they need to improve their own understanding of how to deal with uncertainty but also practitioners' understanding on the same issue, as there exists a clear need to more effectively employ scenario projections of climate change (regional or downscaled) - a major concern on the science-policy interface front. In the past, it has been suggested that help can be provided through explicit policy making modules



in urban modeling (Fragkias and Seto 2007), but new thinking and directions are now needed for dealing with issues of global environmental change.

Several challenges arise with respect to the timing of adaptation action, its nature, cost estimation and its evaluation. The timing of adaptation action is critical and requires scientists and practitioners to establish proper methods for defining trigger points for action based on progressively more refined spatial and temporal climate change information. On the nature of adaptation action, different communities may debate a strict prioritization of goals compared to a flexible or adaptable list of goals in light of knowledge advancement in the field of climate change and the responses to climate change. Reducing the range of current estimates of costs of different types of adaptation can occur through scientific research and the increasing involvement of economists and other social scientists. Monitoring adaptation projects and their outcomes requires the establishment of specific criteria. Clearly, monitoring can occur both globally through major scientific efforts but also locally, through "backyard" solutions. Researchers along with practitioners, thus, need to identify the criteria that will be used for this decision, what can be considered as successful adaptation action in response to climate change, how to eventually evaluate whether adaptation measures were successful or efficient, and more generally, define today what successful adaptation will look like.

Proper application of technology is one of the keys to successful adaptation. Our experience, however, shows that we need new engineering and planning paradigms to accompany it – more flexible, adjustable and robust interventions and plans that consider the huge sums of money that will be required and the large uncertainties that plague the application of the proposed solutions. Attention should be placed on how we can re-engineer old technologies and approaches as well as develop new advanced and transdisciplinary approaches. Furthermore, researchers can potentially take advantage of non-traditional approaches such as distributed systems and technologies that that mimic natural systems – approaches that may hold promise for successful adaptation planning. Opportunities for transfer and diffusion of technology relevant to adaptation to climate change in cities should also be explored.

We also need to better understand the ecology of institutions and scientific networks that will be best suited for synthesizing cross-regional knowledge of the science and practice of adaptation to climate change in cities. A significant amount of work is already under way and we need to quickly put into motion the institutional capacity for synthesis of this work. Eventually, we do not need yet another publication sitting on a shelf of academics, stakeholders and practitioners. Moving one step further, we need to understand how to best integrate fragmented science (both between the social sciences and humanities –economics, political science, ecology, history, philosophy- but also the social sciences and the natural sciences). In particular, we need to find out how we can best systematize existing knowledge on the function of urban systems for a new science and practice of adaptation to climate change. We stumble here on the age-old issue of integrated planning – we need to finally get over the obstacles that lead to existing fragmented approaches and more generally a modular approach in science and planning.

The international dialogue on the issue has brought forward a few areas of conflict and synergy on the theme of urban responses to climate change. The debate over optimal governance structures for sustainability needs to continue: communities may seek either radical or marginal change in social

systems in response to climate change. Adaptation, a concept fundamentally connected to actual change, and clearly related to the functioning of economic systems, has the capacity to bring about change through new governance regimes if the economic and political status quo cannot fulfill targets and expectations set by the respective affected communities. It is unknown whether adaptation projects will be funded by international institutions and organizations if alternative governance regimes are eventually followed in communities across the globe. In short, contemporary political economy paradigms may carry some "strings attached" with significant implications for combined mitigation, adaptation and development action.

Certain dilemmas are also present in the international debate over the new science of adaptation that arise from the need of allocation of scarce resources towards adaptation action: Firstly, researchers may choose to act as if they are discovering something completely new or they can take into account lessons from "analog climates." Either approach may have both shortcomings and advantages that have to be weighed. Scenarios are clearly very helpful, but there is a need to also take advantage of climate response analogies - by examining the history of responses to disasters, for example. Secondly, with regard to the developing world, in particular, while local communities may benefit from traveling climate experts, the choice of training local experts who would remain embedded in the community exists. Thirdly, we expect that top-down simplified guidance mechanisms for smaller and developing countries will be effective in adaptation activity but at the same time, scientists can aim at the creation of bottom-up processes and knowledge. The need to understand vulnerability from different natural and social science perspectives creates a fourth trade-off; namely, the extent to which additional downscaling of global or regional models towards the city or even the neighborhood scale is needed compared to a deeper look at important social factors such as poverty, norms and culture and capacities for individual action. A balance between knowledge from social and natural sciences may benefit the goal of proactive adaptation but also stakeholder engagement. Fifthly, given the long-list of unresolved urban pathologies existing worldwide, adaptation to climate change will not be the only challenge facing urban environments. Urban communities need to increase their capacities to tackle problems concurrently and it is thus important to be looking out for triple win - mitigation, adaptation and development - solutions more intently.

It is important to also recognize that "context is king" for adaptation to climate in cities, as it is for many components of urban sustainability. We see the beginnings of a differentiated landscape of adaptation action with clearly identifiable foci, e.g. on biomes (coastal areas, arid regions, etc.) and social stratification (wealth, formal vs. informal settlements, etc.). Also, issues of equity and justice are beginning to attract more attention as people begin to think about winners and losers from climate change - before and after adaptation action takes place. To the extent that climate change effects lead to a renegotiation of the "social contract", equity and justice issues in the distribution of losses (but also benefits) across populations at different scales become more important since local culture defines, to a large extent, notions of fairness. Thus, a main goal of a new science of adaptation to climate change in cities should be the added "texture" in several undifferentiated or less differentiated topics.

Finally, it is worthwhile to emphasize that cities are complex adaptive systems and science or planning for adaptation that fails to take this into account will not likely be particularly effective in bringing about effective responses to climate change and sustainable urban environments. In particular, urban areas should not ignore emerging complexities that arise from ignored

feedback loops of adaptation action. This discussion can gain substantially from past discussions on planning or designing "good" or sustainable urban form which requires not only an awareness of complex processes of urban growth and land-use change – and its socioeconomic and biophysical drivers - but their connections to ecological functions and vice versa are critical in that regard. Successful local adaptation actions can have serious unforeseen effects in terms of higher population growth and urban physical growth pressures, than previously assumed. For example, successful adaptation action (or perceptions of its success) and the creation of resilient urban communities may bring about new waves of urban population and extent growth pressures that can trump adaptation action in the medium or long term. Cities need to take into account a potential conundrum when considering bidirectional feedback loops in complex system dynamics. In short, scientists and practitioners should be wary of "silver bullet" solutions regarding sustainable pathways in urban development; cities require in- depth analysis regarding the appropriateness of plans, mechanisms and frameworks for different environmental/ecological and institutional contexts as well as different dimensions of sustainability. We are experiencing a fascinating moment in the field of urbanization and global environmental change and it is very important that the scientific community does a better job communicating new science! But practitioners should also be open to a new and evolving science of adaptation to climate change in urban areas.

Note: This contribution partly summarizes and builds upon ideas discussed in a dialogue event that the UGEC project (www.ugec.org) organized in Bonn, Germany within the ICLEI 1st World Congress on Cities and Adaptation to Climate Change in May 2010. This essay reflects comments from Bill Solecki, Paul Kirshen, Dirk Heinrichs, Matthias Ruth, Cynthia Rosenszweig and other unnamed session participants. Many thanks to all for their viewpoints and comments inspiring, informing and enriching this essay.

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