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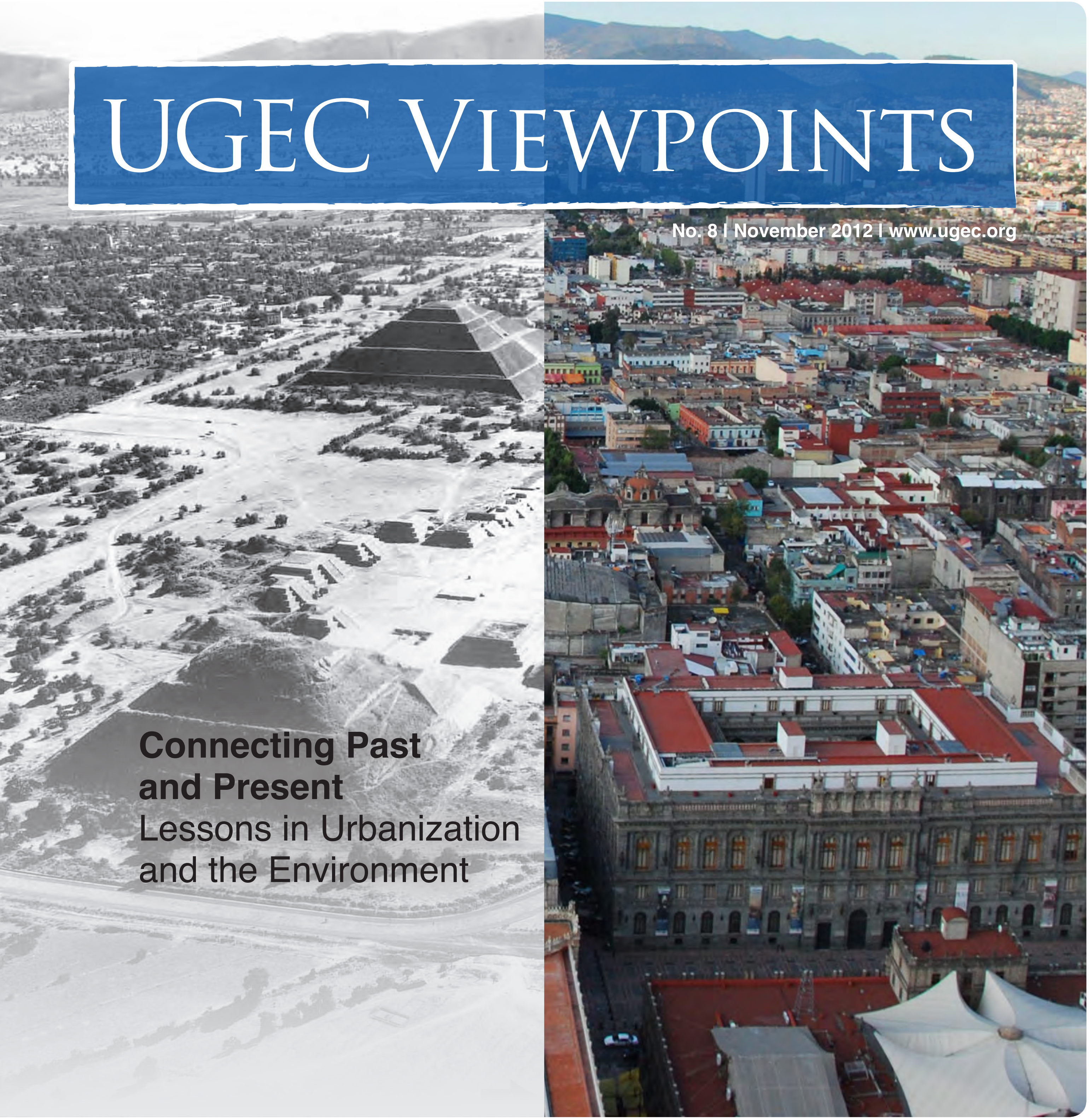

Connecting Past and Present
Lessons in Urbanization and the Environment

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Editorial

Dear friends of the UGEC project,

I am pleased to share with you this eighth issue of *UGEC Viewpoints* which marks a special turning point in my involvement with the UGEC project. As many of you know, I have been working with UGEC as project coordinator since 2009, which has afforded me the great privilege of being part of a dynamic group of international researchers and practitioners – a group that has been instrumental in the advancement of urbanization and global environmental change science and related activities. I am honored to have been given the opportunity to lead the project, as it begins a particularly exciting phase of its lifecycle.

Many of you are not only familiar with, but actively engaged in the process that is currently underway towards creating 'Future Earth' (http://www.icsu.org/future-earth) – a restructuring of the global environmental change research agenda with the overall goal of better responding to the world's pressing environmental and social challenges. This is an extraordinarily worthwhile and equally ambitious endeavor and the UGEC project has been eager from the start to collaborate and share our input; in particular, we've been working to ensure that the 'urban' theme is well-represented as a research priority. It is certainly an exciting time to be a part of the global environmental change research community and additionally, our project is now entering into its third phase or seventh year of operations. These events have provided the opportunity for us to think seriously about how to best shape the future of our project – to remain a strong multidisciplinary programme which will not only work to continue coordinating and facilitating original as well as synthesis research, but also to better promote knowledge exchange, and the interaction and cooperation between researchers, practitioners and decision-makers working under the UGEC theme.

Our world continues to become increasingly urban, and it's clear that the associated sustainability challenges will require collaborative approaches to finding interconnected solutions. This eighth issue of *UGEC Viewpoints* is comprised of regionally and thematically diverse articles, each highlighting research that emphasizes this point. You will read articles which focus on urban adaptation and mitigation responses to climate change and implications for policy, (Patricia Romero-Lankao, Sara Hughes, Angélica Rosas-Huerta, Roxana Borquéz and Melissa Haeffner; Katie Jenkins, Vassilis Glenis, Alistair Ford and Jim Hall; Vincent Viguié and Stéphane Hallegatte), as well as Elena Irwin and Douglas Wrenn's article which stresses the importance of land change modeling for understanding the links between urbanization patterns, policies, and affects on ecosystem services. You will also find articles from two new UGEC project associates Laura Reese (Gary Sands and Laura A. Reese) and Benoit Lefèvre (Benoit Lefèvre and Gautier Kohler), showcasing their research on population dynamics in Mexico City and local emissions trading schemes, respectively. I would also like to draw your attention to the special section: 'Urban Sustainability – What We Can Learn from Archaeology'. The authors (Christian Isendahl; Michael E. Smith; Vernon L. Scarborough, Arlen F. Chase and Diane Z. Chase), many of whom are connected to our sister project, the Integrated History and Future of People on Earth (IHOPE), bring a unique perspective to the issue and quite unlike anything we've had before. Their contributions stress the point that interdisciplinarity is essential when it comes to the study of urban systems, and secondly, that archaeological research can have an important role to play in understanding present-day urbanization. Are there lessons to be drawn from past civilizations that can help guide our efforts in creating sustainable cities now and into the future?

I look forward to the years ahead with the UGEC project and for the new and continued collaborations that will take shape and grow. I thank the readers for your continued interest and engagement with the project and for the warm welcomes I have received from so many of you during this transition into my new role. Finally, I would be remiss to not briefly acknowledge my good friend and colleague, Michail Fragkias, for whose expertise, advice, and continued support I am forever grateful. Thanks, Michail.

Enjoy the issue!

Corrie Griffith
UGEC Executive Officer

Table of Contents

4
Beyond Adaptive Capacity Checklists: Examining the Construction of Capacity in Mexico City and Santiago
Patricia Romero-Lankao, Sara Hughes, Angélica Rosas-Huerta, Roxana Borquéz and Melissa Haeffner

8
A Probabilistic Risk-Based Approach to Addressing Impacts of Climate Change on Cities: The Tyndall Centre's Urban Integrated Assessment Framework
Katie Jenkins, Vassilis Glenis, Alistair Ford and Jim Hall

12
Trade-Offs and Synergies in Urban Climate Policies: A Case Study in the Paris Urban Area
Vincent Viguié and Stéphane Hallegatte

Urban Sustainability — What We Can Learn from Archaeology

15
The Role of Ancient Cities in Research on Contemporary Urbanization
Michael E. Smith

20
Low-Density Urbanism, Sustainability, and IHOPE-Maya: Can the Past Provide More than History?
Vernon L. Scarborough, Arlen F. Chase and Diane Z. Chase

25
Investigating Urban Experiences, Deconstructing Urban Essentialism
Christian Isendahl

29
Are City-Based Emissions Trading Schemes Efficient Instruments for Reducing Local GHG Emissions?
Benoit Lefèvre and Gautier Kohler

34
Mexico City in the 21st Century: Population Dynamics and Policy Responses
Gary Sands and Laura A. Reese

41
Developing Spatial Economic Models of Land Change for Policy Simulation
Elena G. Irwin and Douglas Wrenn

45
Contributors

46
About the UGEC Project
About the IHDP

47
About the Global Institute of Sustainability

Santiago, Chile

Beyond Adaptive Capacity Checklists: Examining the Construction of Capacity in Mexico City and Santiago

Patricia Romero-Lankao, Sara Hughes, Angélica Rosas-Huerta, Roxana Borquéz and Melissa Haeffner

Cities are vulnerable to a range of environmental hazards that are likely to be exacerbated by climate change: floods, droughts, poor air quality, and heat islands are a few examples. Assessments of this vulnerability often include an evaluation of a city's adaptive capacity, or its potential to respond to changes in the frequency or severity of environmental hazards as well as its ability to take advantage of or mitigate these changes. For example, at the city (e.g., institutional) level, a common metric of adaptive capacity is the availability and effective use of information. In many cases, a city would receive a yes/no rating, or perhaps a score between 1 and 10, to indicate an existing quantity of adaptive capacity embodied in the city's decision-making processes and institutions. However, from both a research and practitioner perspective this method of assessment is not able to produce a useable understanding of the mechanisms and systems that underpin the availability and effective use of information in a city agency.

In an effort to address this challenge in urban vulnerability research we have undertaken a comparative study of the construction of adaptive capacity in two Latin American cities: Santiago de Chile and Mexico City, Mexico. This work is one outcome of the Inter-American Institute-funded ADAPTE project (ADaptation to the health impacts of Air Pollution and climaTE extremes in Latin American cities) that has supported an international team of researchers in Santiago, Mexico City, Buenos Aires and Bogotá[1].

Environmental planning, risk and vulnerability in Latin American cities

Cities in Latin America are simultaneously facing pressure to meet development aims (e.g., water service provision, housing needs) and respond to the potential effects of climate change. As a result, Latin American cities have a policy agenda that is both local and global. The region's population is nearly 80% urban, and demands for housing and economic opportunities currently outpace development, thus challenging the achievement

1 The results of the research will be published in: Romero Lankao, P., Hughes, S., Rosas Huerta, A., Borquéz, R., Qin, H., & Lampis, A. (2012). Toward an integrated assessment of urban vulnerability and risk: insights from Latin American cities. *Environment and Urbanization* (under review).

of sustainability goals. Neoliberal reforms are an additional globalizing force: open markets and decentralized decision-making have helped to change the role of Latin American cities in national and global economies. Climate change is but one example of this restructuring. Cities in Latin America are actively participating in transnational networks such as ICLEI - Local Governments for Sustainability and their representatives have been attending the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties sessions. Despite their economic and social importance to the region and the world, Latin American cities have been particularly understudied in terms of the complexity of factors that determine urban vulnerability and risk at the city level, and their capacity to respond and adapt to these hazards.

Mexico City and Santiago present useful case studies for evaluating the construction of adaptive capacity in Latin American cities. In both places, climate models predict that mean temperatures will increase and mean precipitation will decrease with climate change. Both cities are also expected to experience more intense droughts, heat waves and flood events. Economically, the two cities are the hubs of their country's economies, generating 34% (Mexico City) and 43% (Santiago) of national GDP. One difference between the two cities is the timing of their response to these predicted changes. Mexico City has been an early actor in taking steps to mitigate and adapt to climate change, while Santiago is in the process of releasing its first climate change action plan. Using these two cities, therefore, allows us to compare the challenges and opportunities that early and late actors experience in building or leveraging adaptive capacity.

Research methods

We used four metrics of institutional adaptive capacity to guide or investigation: (1) cooperation between different governmental sectors and levels, and between governmental authorities, NGOs, citizens, and experts; (2) a legal framework that shapes strategic regulation of emitting sectors, risk management, and flexibility; (3) mechanisms by which the public and stakeholders are able to participate and be represented in decision-making; and (4) the availability, exchange, and use of information for decision-making (Adger et al., 2007; Engle & Lemos, 2010; Moser & Satterthwaite, 2008; Pelling & High, 2005). While not necessarily comprehensive, they provide a basis with which to evaluate the construction of adaptive capacity in urban policy making.

We conducted interviews with decision-makers, managers, and representatives from academic and non-governmental organizations to understand the processes through which adaptive capacity is created or eroded. The interviewees were asked about their role in climate planning; how they use, access, and share information; the mechanisms through which they engage with communities or encourage participation; and their perception of how, and how well, the legal framework in their city is suited to addressing the challenges of climate change.

> Cities may face similar constraints despite an early actor advantage and this is due to the fact that adaptive capacity is the product of broader political and institutional features of urban governance.

Results

Actor networks

An important insight from this study is that climate change planning – and even environmental planning more broadly – is firmly embedded within the broader structures of each city's politics, funding priorities and constraints. While cooperation and coordination are key components of adaptive capacity, there are very few mechanisms in place to allow or encourage coordination across sectors or levels of government in political systems that have no legacy of this type of governance. In centralized systems like those in these Latin American cases, urban policy agendas can be dominated by federal funding priorities and local authorities are left without the means to take action to effectively manage vulnerability and risk. In both Santiago and Mexico City climate change is housed in the environmental sector, which is often already marginalized within city politics. Turnover is an additional barrier to longer-term relationship-building because administrators and politicians are often in office for a single three-year (Mexico) or four-year (Chile) period.

Mexico City

Leadership may be one effective tool for building broader networks for collaboration. In the case of Mexico City, former mayor Marcelo Ebrard took a very active role in building the climate policy agenda. His efforts generated programs and funding streams that are helping maintain momentum behind climate change planning.

Legal framework

Both Santiago and Mexico City have a longer-term tradition of disaster management that has helped to define the legal framework in which climate change planning is embedded. However, interviewees in both cities see disaster management as reactive rather than proactive. This may be due in part to the fact that climate change and preventative programs are secondary to other development concerns, such as estate development and housing. Furthermore, some of the departments and ministries that would like to (or need to) work on addressing climate change do not have the legal backing to do so.

One difference between the two cities is the degree to which the legal and regulatory tensions between development and conservation (particularly in land-use) are explicit. In Mexico City there is a distinction between zones for development controlled by the Urban Development Program and zones for conservation controlled by the General Program for Ecological Planning. In Santiago, urban growth is prioritized through programs such as Priority Areas for Urbanization and Conditional Urbanization Areas; there is no explicit mechanism for managing land for environmental purposes (such as recharging aquifers or maintaining open space).

Participation

Participation mechanisms for climate change planning in both cities primarily consisted of workshops and consultation processes with other government agencies, academics, and NGOs. There was very little involvement of the public and community members, due largely to two factors: a perception in the government of public apathy and ignorance and a political culture that does not traditionally value or encourage direct public engagement in decision-making. One Mexican authority said, "We need to break the apathy of the population. They don't respond. They don't ask for accountability. They are apathetic. So there is a lot of inertia among many decision-makers and we need to address that and make sure that climate change is considered a priority."

One opportunity for improving participation comes again from disaster management, which is rather unique in the two cities with its ability to engage communities, and the sector has a history of communicating directly with vulnerable households. Building on disaster management's public engagement mechanisms for climate change planning could be a useful strategy for bringing communities and their views into the process.

Availability and use of information

Climate change is a relatively new policy area in both Santiago and Mexico City, though Mexico City has been engaged with climate change science and planning for a longer period of time. Because of this relative newness, the information needed or desired for climate change planning is not always available. In particular, both cities are lacking an understanding of local risks and vulnerabilities and climate scenarios on which to build adaptation strategies. New types of information are needed. In addition, the information that does exist is dominated by technocratic approaches to climate change planning and is largely in the hands of federal authorities. The transmission of information is top-down due to both a real and perceived lack of capacity at the local level.

One innovation in Mexico City is the Virtual Climate Change Center, a platform established by the city government and the National University of Mexico (UNAM) to facilitate information sharing between decision-makers and researchers.

Decision-makers are encouraged to share their information needs and researchers work to stay current and relevant in climate science. This is a new model for the city and could prove to be an effective tool for improving the availability and use of information in climate change planning.

First conclusions

The findings from this project have demonstrated two important features of urban adaptive capacity: cities may face similar constraints despite an early actor advantage and this is due to the fact that adaptive capacity is the product of broader political and institutional features of urban governance. While Mexico City is beginning its third stage of climate change planning, Santiago is set to release its first plan in September 2012. However, both cities face similar challenges to building and exercising their adaptive capacity in the form of networked actors, an effective legal framework, public participation, and the use of information in decision-making. This is due in large part to the ways in which the broader system of urban governance shapes these features of adaptive capacity. Urban governance in Santiago and Mexico City prioritizes growth and development and operates in a highly top-down political system. Increasing adaptive capacity in these cities would require broader shifts in the institutional landscape.

Our aim with this research and with the ADAPTE project more broadly is to generate a more nuanced understanding of urban vulnerability and risk. The pathways and mechanisms through which environmental hazards, communities, and governance systems interact are interdependent and nonlinear. Future work should continue to explore these dynamic relationships in Latin America with the aim of fostering resilient and sustainable cities.

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Canary Wharf Docklands Station in London

A Probabilistic Risk-Based Approach to Addressing Impacts of Climate Change on Cities: The Tyndall Centre's Urban Integrated Assessment Framework

Katie Jenkins, Vassilis Glenis, Alistair Ford and Jim Hall

Urban areas are considered to be particularly vulnerable to the economic and social impacts of climate change due to their high concentrations of people and assets (Hall et al., 2009), and due to the Urban Heat Island (UHI) effect which can further amplify high temperatures. Over the last decade there has been a growing awareness of the role that cities have to play in both mitigating and adapting to climate change. Whilst mitigation strategies may reduce the likelihood of climate-related risks occurring in the longer-term, in the short-term, information is required to help governments and policy makers prepare for such risks, to identify and implement robust adaptation measures, and improve the resilience of cities.

However, the scale and severity of economic and social impacts not only reflect climate and weather patterns but are also dependent on the underlying vulnerability and exposure of affected regions and populations. Evidence suggests that societal change and economic development have been principal factors in the documented increase in economic losses from weather extremes over the 20th and early 21st century (Höppe & Pielke, 2006), although climate change is likely to play a more dominant role in the future given the recent projections of the IPCC (2012). Consequently, the development of adaptation strategies for urban areas requires integrative thinking to understand and model relationships between the built environment, land-use, infrastructure systems, the urban economy and climate. Yet, given the range of different actors and policies in contrasting sectors of urban areas, working at different spatial and temporal scales, developing fully integrative strategies can be complex and challenging to achieve (Walsh et al., 2011), with the focus often remaining on single dimensions of urban problems (Sánchez-Rodríguez, 2010).

Tyndall Centre's Urban Integrated Assessment Framework (UIAF)

Such considerations underpinned the development of the Tyndall centre's UIAF which was established to simulate processes of long-term change at the city-scale. This enabled the exploration of a wide range of climate, land-use and socio-economic scenarios and their implications, providing a whole-system approach to assessing adaptation strategies to enhance future urban sustainability. The framework facilitated a quantified assessment of climate change impacts and adaptation to analyse and support climate-related decisions in cities (Hall et al., 2009). However, research challenges remained including the incorporation of feedbacks between the model components and the need to expand the range of impacts and adaptation options incorporated. Furthermore, city-scale climate change impact assessments which use a scenario-based approach can lack the capacity to provide information on the probabilities of extreme weather events, their characteristics, related impacts, and the implications of this for adaptation policies.

Model developments

Consequently, the UIAF has been extended (Figure 1) to enable a probabilistic risk-based approach by incorporating probabilistic projections from the UKCP09 spatial Weather Generator (WG), for a variety of climate and emission scenarios. The version of the WG used also includes a representation of the UHI effect through the incorporation of urban land-use and anthropogenic heat emissions. The innovative framework can be applied to various weather variables facilitating the systematic analysis of numerous direct and indirect social and economic impacts of weather extremes.

Secondly, interactions and feedbacks between the climate impact assessment and the land-use transport model, and the impact assessment and economic input-output (IO) model have been established to allow a more detailed assessment of urban vulnerability and indirect economic impacts which may occur. City-scale assessments of the impacts of climate change have predominantly focused on direct impacts only. However, the propagation and amplification of direct impacts within cities can be large, potentially extending far beyond the temporal and spatial extent of the original event. Additionally, the regional application of the UIAF (originally focused on Greater London) has been extended (Figure 2). This has been defined based on the spatial boundary of London's influence with respect to key drivers, such as employment and commuter journeys, to establish the region which can be considered intrinsically linked to the capital. This allows the model to capture the full economic impacts to London of climate-related disruption. Thus, the extended UIAF provides a more comprehensive and probabilistic analysis of the full consequences of extreme weather events on urban systems, as well as facilitating an assessment of the underlying climate model uncertainties[1].

Figure 1 | The extended integrated assessment framework for assessing adaptation and resilience in cities

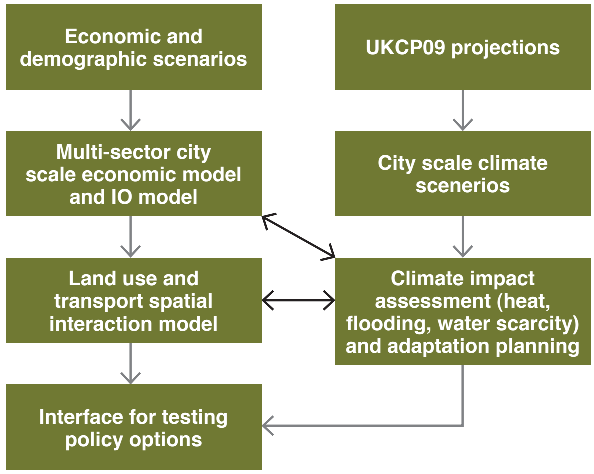
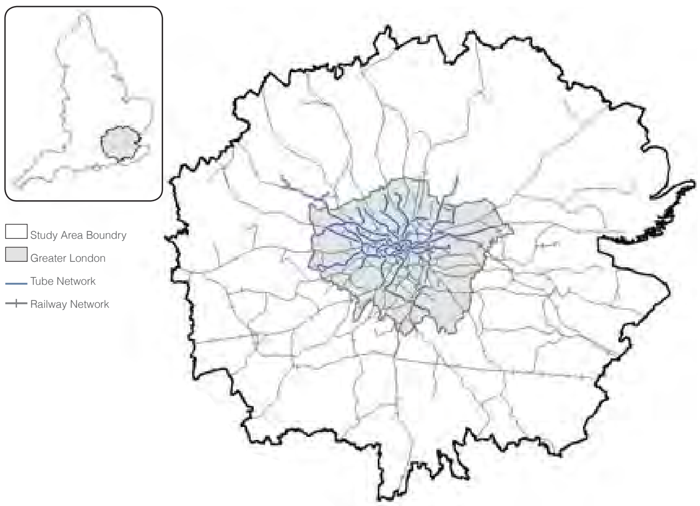


Figure 2 | ARCADIA study area



Application of the UIAF

To illustrate the benefits of the extended UIAF the potential application to the assessment of heat risk on railway buckle events is outlined. The impact of climate change on rail buckle frequency and travel delay costs has been the focus of previous scenario-based studies which provide outputs aggregated at a regional level (e.g., Dobney et al., 2009). However, as the effectiveness of a city's transport system is central to business, employees, and economic

1 Further details on the project can be found at: http://www.tyndall.ac.uk/research/cities-and-coasts/arcadia and http://www.arcc-cn.org.uk/project-summaries/arcadia/

> Cities are complex systems and the analysis of climate change impacts needs to be dealt with in a way which recognises and captures both these complexities and uncertainties. Probability-based estimates of impacts at relevant spatial scales can provide policy makers with more relevant and detailed risk-based information.

competitiveness, damage to the system could be much more severe and far-reaching and implications in terms of congestion can have an equally important economic cost (Houghton et al., 2009). The extended UIAF allows a probabilistic and spatially explicit study of both direct costs of rail-buckle events in terms of repair costs as well as an assessment of the implications of transport disruption for commuters and train operators, and indirect economic consequences for businesses of reduced labour productivity.

Temperature thresholds, defined to represent buckle risk, can be applied to daily maximum temperature data from the WG to provide a probabilistic assessment of the number of days when one or more buckle events could occur. When applied to the ARCADIA[2] study area the analysis indicated that the frequency of buckle events and related repair costs would increase in the future compared to the baseline period under all scenarios (results are displayed in Figure 3 at various percentiles). Given that network capacity is set to increase in the future, this highlights the need to invest in upgrading track quality to increase resilience to high daily temperatures and heatwave events, particularly on key commuter routes.

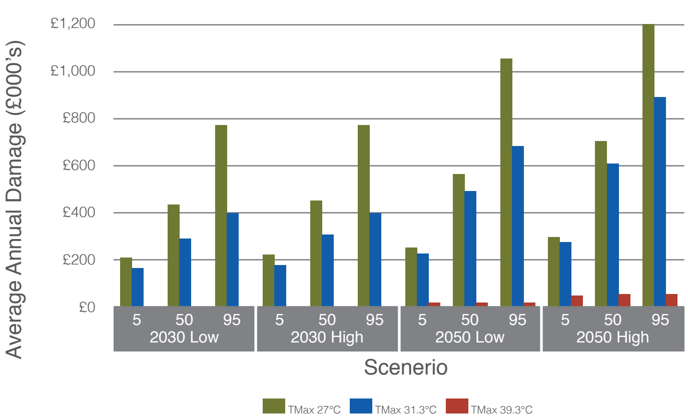
Secondly, as the UIAF facilitates interaction between the impact assessment and the transport model, the spatially explicit information on buckle events can also be superimposed on the underlying railway network. The transport model covers public and private networks, constructed of links and nodes, with costs on each link. Costs are a function of a number of attributes such as distance, speed, and capacity. If the level of service drops below the current level then a reduction in demand or switch to other destinations or modes which give the lowest cost route is expected. This allows the transport model to estimate travel delay minutes and the associated economic costs of buckle-related disruption to both commuter journeys and rail operators.

Thirdly, feedbacks can also be included between the impact assessment and the economic IO model, which includes labour supply as a function of each sector's productivity. The impact of buckle events on commuter delay minutes can be used as an input into the IO model which assesses the indirect impact of reduced labour productivity on the wider economy. The suite of direct and indirect buckle-related impacts can be presented individually or aggregated to provide a more comprehensive estimate of the total economic costs of heat-related impacts on the railway network.

Policy implications

Cities have emerged as first responders in adapting to and mitigating climate change (Rosenzweig et al., 2011). It is important that these responses are driven by sound and timely information on future risks due to climate change and that such information is presented in a way which is relevant to policy

Figure 3 | Impact of track condition on average annual damage from rail buckle events for poor track (TMax 27°C), moderate track (TMax 31.3°C), and good track (TMax 39.9°C) at the 5th, 50th, and 95th percentile for a variety of scenarios



2 ARCADIA is Adaptation and Resilience in Cities: Analysis and Decision making using Integrated Assessment. The project aims to provide system-scale understanding of the inter-relationships between climate impacts, the urban economy, land use, transport and the built environment and to use this understanding to design cities that are more resilient and adaptable. See: http://www.arcc-cn.org.uk/project-summaries/arcadia/

makers and stakeholders. The development of a stakeholder policy tool is one way in which to enhance engagement with stakeholders, share information, and help develop adaptation strategies to enhance the future resilience of cities.

The application of the UIAF to heat-related buckle events highlights the importance of modelling interactions in the urban system in the face of climate change. The risk from heat-related buckle events is likely to become much more significant when assessed at a more detailed and integrative level. This approach can provide more comprehensive information for policy makers such as the range of possible temperature regimes which railways could be operating under in the future, which will have implications for track standards and future maintenance practices. In this example, benefits could be gained by investing in maintenance and track upgrades; the spatial nature of the outputs can provide an overview of potential hot spots; and consideration of indirect economic impacts would provide more comprehensive coverage of the potential consequences of climate change on the railway network, on businesses and on the competitiveness of the city as a whole.

Secondly, cities are complex systems and the analysis of climate change impacts needs to be dealt with in a way which recognises and captures both these complexities and uncertainties. Probability-based estimates of impacts at relevant spatial scales can provide policy makers with more relevant and detailed risk-based information. Presenting model outputs in this way means they are consistent with risk management frameworks common to many actors and sectors involved in urban planning and decision making. A probabilistic risk-based assessment also allows policy makers to account for societal risk aversion in their decision making, and as our understanding of problems evolve then the impact of this new knowledge on uncertainty can also be addressed to provide a more adaptive decision making process (Webster, 2003).

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Paris, France

Trade-Offs and Synergies in Urban Climate Policies: A Case Study in the Paris Urban Area

Vincent Viguié and Stéphane Hallegatte

Around the world, cities are at the forefront of climate policies. Land-use planning, urban transport and housing policies are recognised as major tools of both climate change mitigation and adaptation. However, urban climate policies are not developed or implemented in a vacuum; they interact with other economic and social policy goals. These interactions can lead to trade-offs and implementation obstacles, or to synergies and win-win strategies. Despite a growing number of innovative urban climate strategies, little analysis investigating their effectiveness exists, in part because it requires a broad interdisciplinary approach that includes economics, urbanism, climate sciences, engineering and hydrology. Integrated city models can help address this issue.

Balancing different objectives

Transport and land-use planning policies play a key role in greenhouse gas (GHG) emissions reduction. They can influence both total transport demand (km travelled per person) as well as modal choice. Housing policies can help achieve dramatic energy consumption reduction at a very low cost. These policies also play an important role in cities' vulnerability to climate change impacts. Flood risk exposure, for instance, is strongly determined by land-use planning policies. Vulnerability to heat-waves depends on building characteristics (insulation, for instance) as well as on urban planning policies that address the urban heat island effect. However, in practice, it is difficult to efficiently use these policies as tools to address climate-related issues, because they are only some of the many issues that urban decision-makers must take into account. They must also consider economic competitiveness, access to affordable housing, quality of life, etc. Climate policies have an impact on each of these issues, leading to interactions between the policy goals, i.e., synergies or conflicts.

Ideally, environmental policies will result in positive feedbacks with respect to economic and social issues. This occurs when, for instance, a policy that decreases car congestion increases residents' quality of life, enhances economic competitiveness, reduces accessibility inequalities among neighborhoods, and decreases air pollution and GHG emissions. However, sometimes the opposite occurs. For example, while enlarging parks and introducing more vegetation in cities can be useful for adapting cities to higher temperatures and can improve quality of life, such actions may also reduce population density and lead to increased GHG emissions from transportation (McEvoy et al., 2006; Hamin & Gurran, 2009). Similarly, protecting urban coastlines with dikes and seawalls decreases cities' vulnerability to floods, but can reduce recreational amenities and attractiveness to tourists, thereby reducing inhabitants' incomes and slowing down development. These policies also have consequences for property values, which in turn influence the attractiveness of an urban area for potential residents, professionals, and businesses. These effects can vary by community or location, e.g., impacting suburbs versus the city center, leading to unintended redistributions of wealth or amenities that may or may not be consistent with policy goals.

Transport policies, land-use planning policies, accommodation prices and natural hazard exposure interlinkages

Such conflicts among different policy goals create implementation problems, while synergies offer opportunities for win-win solutions - suggesting the utility of assessing all urban policies within a unified framework. Such a task requires a broad interdisciplinary approach that includes economics, urbanism, climate sciences, engineering and hydrology. In this context, Integrated City Models (ICM) (see for instance, Dawson et al., 2010) are pertinent tools. ICM are highly simplified representations of reality that describe the most important drivers of city change over time and can assess the consequences of various policy choices. ICM can provide decision-makers and stakeholders with useful information and can help them understand the main mechanisms and linkages at work.

In a recent paper published in *Nature Climate Change* (Viguié & Hallegatte, 2012), we show how such a model enables, going beyond qualitative work available thus far, a first quantification of these conflicts and synergies. In particular, we show how flood zoning and greenbelt policies may only be accepted if combined with transportation policies: when not mainstreamed within urban planning, stand-alone adaptation and mitigation policies are unlikely to be politically acceptable.

To get to this result, we have used a novel model calibrated on the Paris Urban Area, NEDUM-2D, and we have undertaken a multicriteria analysis of several urban policies, namely, a greenbelt policy, a public transport subsidy and a zoning policy to reduce the risk of flooding. We have assessed these policies using five indicators that take economic, social, and environmental policy goals and implementation obstacles into account.

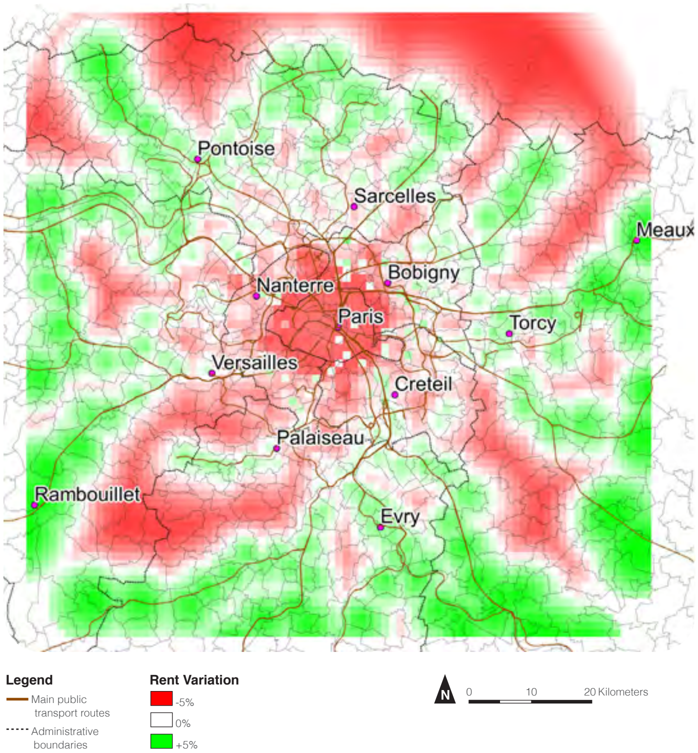
The three policies we have chosen give a good illustration of the interwoven character of various policy goals. A greenbelt policy, i.e., land-use regulations which prohibit building in areas not already densely inhabited, is an example of an urban planning policy which aims at managing urban sprawl. Like the other urban planning policies which aim at slowing city expansion, it has an *a priori* positive impact on GHG emissions. Indeed, it may contribute to reducing the average distance driven by inhabitants, as it limits city size. It can increase public transport modal share by favoring densification as opposed to sprawl.

As a regulation, the greenbelt policy has no direct cost for the city budget, but it might encounter some opposition because of its side effects. Such a policy may indeed lead to increased real estate prices and rents, as it limits building space. Other unintended and more subtle effects are also sometimes observed. For instance, this increased land scarcity can lead to more people living in flood-prone areas existing in the city, as it gives an extra incentive to build on every surface available. Such a phenomenon has been observed and measured in the United States (Burby et al., 2001; The World Bank, 2010). A strict zoning policy which manages to prevent any new construction in flood-prone areas enables a 'canceling out' of this side-effect, however, it increases land scarcity and contributes to increased rents and real estate prices.

Public transport subsidies can be decided for a variety of reasons. As they favor an increase in public transport modal share, they can also contribute to reducing greenhouse gases emissions. However, such a policy might encounter some opposition because of its distributional impact. As it is costly, it ultimately leads to increased taxes, but the citizens who will have to pay are not the same as those who will benefit from the policy. If maintained over the long term, public transport subsidies give an incentive to live further from the center of the city. This is a positive result, as better accessibility to the city center from the suburbs is an important factor contributing to decreasing real estate prices in the center. However, it also leads to an increased urban sprawl.

Greenbelt policy and public transport subsidies are two policies with different scopes and different objectives. However, both of them implicate the same variables: real estate prices, urban sprawl, emissions, etc. They actually appear rather complementary: whereas the greenbelt policy tends to increase real estate prices in the center, the transport subsidy decreases them. Whereas the transport subsidy tends to increase urban sprawl, a greenbelt policy can stop it.

Figure 1 | Example of the impact of a public transport subsidy on rents (Viguié & Hallegatte, 2012)



Despite a growing number of innovative urban climate strategies, little analysis investigating their effectiveness exists, in part because it requires a broad interdisciplinary approach that includes economics, urbanism, climate sciences, engineering and hydrology.

Managing trade-offs and synergies in the Paris urban area

The ICM we have developed, NEDUM-2D simulates households' location and travel choices, and computes rent levels across a city (Figure 1). It enables a quantification of the magnitude of the side-effects we have described. It therefore helps to understand to what extent it is possible to minimize the trade-offs between objectives by taking advantage of the interactions between different policies. Here, for instance, implementing both a greenbelt policy and public transport subsidies may attenuate unwanted side effects of both policies.

We were able to compute that well-chosen land-use policy, public transport subsidies and flood-risk zoning could actually manage to stop urban sprawl in the Paris urban area, while decreasing accommodation prices in the center of the city, and preventing flood-risk exposure increase, with limited redistributive impacts[1].

Obviously, it does not mean that win-win strategies are always available, and in every city. In some cases, trade-offs will remain unavoidable and urban decision-makers will need to make tough choices. However, even though the institutional fragmentation of urban policies does not always allow for such an integrated decision-making process, this type of analysis may help identify policiy mixes that are more efficient and have higher political acceptability than stand-alone policies.

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1 We assume that redistribution purposes are best taken care of through specific redistributive policies.

Teotihuacan, Mexico

The Role of Ancient Cities in Research on Contemporary Urbanization

Michael E. Smith

The work of the UGEC project focuses on contemporary cities and policy implications for the future. Why should researchers in this area pay attention to ancient cities? After all, modern cities differ significantly from their premodern antecedents, and archaeological and historical data are very incomplete about key urban processes. Nevertheless, I suggest that ancient cities are relevant to research on contemporary urbanization in two realms: comparison and long-term change.

A consideration of ancient cities, such as the pre-Aztec metropolis of Teotihuacan, Mexico (Figure 1) expands the sample of cities that scholars and policy-makers can draw on for comparative insights.[1] Cities are complex phenomena, and a broader base for comparison reveals the patterns of variability among cities. A larger sample helps scholars to distinguish universal urban patterns from unique occurrences, and general trends from idiosyncratic events. Cities have been built in many different ways over the ages, and urban life has found a wide variety of expressions throughout history. A comparative approach is needed to comprehend, and benefit from, this variability.

Including ancient cities in our frame of reference also allows for study of long-term change. Archaeology furnishes a record of urban success and failure over thousands of years in many parts of the world (Marcus & Sabloff, 2008). Why did some cities flourish for centuries while others grew and declined over a decade or two? Although archaeologists cannot yet claim to have definitive answers for such questions, we do have the data to address them. As we transform our primary data into patterns of historical urban transformation, the results may very well help scholars understand issues relating to modern cities and environmental change.

The last point brings up a caveat: archaeologists have relevant urban data but few rigorous results to date. Comparisons based on one or two cities may provide insights, but they can also be incomplete and even misleading. Teotihuacan (Figure 1) resembles modern Phoenix (Figure 2) in many ways. Both are large grid-planned cities in arid or semi-arid environments with early economies that relied on irrigation agriculture. Perhaps research on

1 Teotihuacan, which flourished between AD 100 and 600, is one of the most extensively studied ancient cities in Mexico, in part due to a series of research projects directed by Arizona State University Emeritus Professor George Cowgill (Cowgill, 1997; 2008; Millon et al.,1973) ASU archaeologist Saburu Sugiyama continues the university's research program at the site, and ASU runs the Teotihuacan Research Laboratory, one of the premier archaeological research facilities in Mexico.

Figure 1 | The central Mexican city of Teotihuacan (AD 100 – 650). *Arial photograph from 1965, by Compania Mexicana de Aerofoto*

Figure 2 | Phoenix, Arizona. *Photo by Melikamp, from Wikipedia (Creative Commons Attribution-Share Alike 3.0 license)*

Source: http://en.wikipedia.org/wiki/File:Phoenix_AZ_Downtown_from_airplane.jpg

Teotihuacan and its fate – five centuries as a flourishing economic and political center, followed by collapse and abandonment – can suggest insights about the future of Phoenix. But a more rigorous approach would aggregate data from a larger sample of ancient cities to draw comparative insights about urban dynamics.

Unfortunately, archaeologists have not yet carried out the kinds of targeted comparative analyses required to integrate the results of many diverse fieldwork projects. During the past few decades my colleagues and I have been piling up an impressive amount of data about past societies, but efforts to synthesize the new finds are still in their infancy (Smith, 2012). In a recent paper (Smith, 2010c) I review three topics in contemporary urban research – urban sustainability, sprawl, and squatter settlements – and show that archaeologists now have data on all three phenomena for past cities (including Teotihuacan), but we have yet to make solid contributions because of our lack of syntheses targeted at these issues.

A closer integration of archaeology with both the social and natural sciences can expand the breadth of research on urban issues. The best contemporary research on urbanization – including the UGEC project – is transdisciplinary in nature. Archaeology can now be regarded as a social science of its own, not merely a sub-discipline of anthropology or history (Smith et al., 2012). Archaeology brings a distinctive set of data and concepts to the table to expand research on cities and other social phenomena (Smith, 2010b).

Urban organization through the ages

My first example is a transdisciplinary research project based in the School of Human Evolution and Social Change at Arizona State University. The project, titled "Urban Organization through the Ages: Neighborhoods, Open Space, and Urban Life," is a team effort by six faculty: three archaeologists (Barbara Stark, George Cowgill, and myself), a geographer (Christopher Boone), a political scientist (Abigail York), and a sociologist (Sharon Harlan). We are part of a series of innovative transdisciplinary projects collectively titled, "Late Lessons from Early History," funded through ASU's Intellectual Fusion Investment Fund.

The participants in our project share interests in urban form and urban life – particularly neighborhood dynamics – and a broad comparative view of urbanism. One of our first efforts was to examine the dynamics of ethnic and class clustering in cities across time and space. We discovered that patterns of segregation and clustering are enormously diverse across history, with a variety of top-down and bottom-up drivers generating (or inhibiting) clustering in different circumstances (York et al., 2011). We found that there is no such thing as a "typical" city in any urban tradition (such as medieval Europe or the Islamic Near East). One lesson is that urban dynamics require explanation on the level of individual cities and regions, and that it is fruitless to search for typical patterns. Our findings on the antiquity and universality of urban neighborhoods (Smith, 2010a) dovetail with research on modern neighborhoods (Sampson, 2012).

Another activity of our joint project was to examine the nature of urban open spaces from a comparative perspective. Open space in cities takes many forms, from large public plazas to neighborhood parks. We identified seven types of open space and examined their occurrence throughout history at various spatial scales, from the entire city to individual blocks. Our typology is described in Stanley et al. (In press), and we also have published several individual comparative studies of different kinds of urban open spaces (Stanley, 2012; Stark, In review).

For our next project we plan a study of inequality in access to urban services in two samples of premodern cities: archaeological cases and historical cases. Outside of a few studies of medieval cities, no one has yet to examine service access for cities before the modern era. We know that ancient cities had high levels of wealth inequality, but did wealth inequality extend to unequal access to basic services? What is the range of variation among premodern cities and how can it be explained? By digitizing maps and conducting GIS spatial analyses of premodern cities, we aim to understand urban services and patterns of inequality in the past that we will compare to what is known of modern cities. This kind of systematic comparative research is necessary in order to produce reliable, systematic knowledge that can aid scholars of modern urbanism.

> Cities have been built in many different ways over the ages, and urban life has found a wide variety of expressions throughout history. A comparative approach is needed to comprehend, and benefit from, this variability.

Figure 3 | The temple of Angkor Wat in the city of Angkor, Cambodia. *Photo by Bjørn Christian Tørrissen, from Wikipedia (Creative Commons Attribution-Share Alike 3.0 license)*

Source: http://en.wikipedia.org/wiki/File:Angkor_Wat.jpg

Current archaeological research on ancient cities

Low-density cities

Archaeologist Roland Fletcher has developed a model of tropical agrarian, low-density urbanism (Fletcher, 2009; 2012) to describe ancient societies such as the Classic Maya and the Khmer of Angkor. The earliest archaeologists were attracted to these sites by the monumental architecture – those features that attract tourists today. The towering temple of Angkor Wat, located in the Khmer city of Angkor, is a good example (Figure 3).

From the perspective of comparative urbanism, spectacular temples are less interesting than residential zones. Groups of three or four houses were arranged around a patio and were surrounded by considerable open space. Today these spaces are filled with jungle vegetation, but in the past the area between house groups was farmed intensively. Archaeologists are working on this issue at Angkor, but for the similar Maya cities of Central America chemical analyses of urban soils reveal traces of phosphates from ancient fertilizers (Isendahl, 2010). Archaeologists are showing that urban agriculture is nothing new (Barthel & Isendahl, 2012); tropical city-dwellers and others have been practicing it for millennia.[2]

Neighborhoods have distinctive spatial expressions in low density cities, where they take the form of spatial clusters of houses (Smith, 2011). The configuration of house groups interspersed with cultivated areas produced a level of urban sprawl comparable to the automobile-generated sprawl of contemporary U.S. cities. Figure 4 shows the extent of Angkor, as recently mapped by Fletcher's team (Evans et al., 2007), at the same scale as a density map of metropolitan Phoenix. The mechanisms that generated ancient and modern sprawl probably differ greatly, although there is still little systematic research on ancient sprawl.

Ancient urban sustainability

Many definitions of sustainability include longevity – the length of time over which a particular practice or society survives (Denevan, 1995; Patten & Costanza, 1997), and this factor has been applied to urban sustainability by Grant (2004). Archaeologists have an abundance of data on the longevity of

2 See also "Aztec Urban Agriculture," http://wideurbanworld.blogspot.mx/2011/11/aztec-urban-agriculture.html.

settlements. The caveat mentioned above (that archaeologists have yet to conduct systematic research that synthesizes a large sample of cases) holds for urban sustainability, but it is possible to make some preliminary observations.[3]

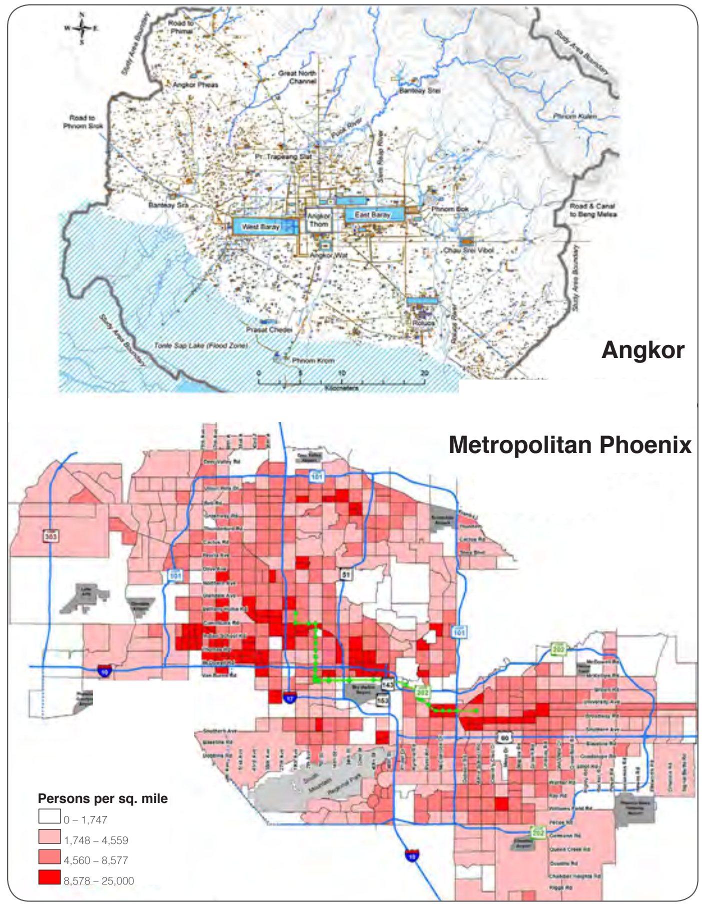
As an example, I consider longevity for archaeological cities and towns located in a full-coverage, regional survey of the valley of the Yautepec River in the Mexican state of Morelos (Smith, 2006). With the exception of site 200, none of these urban sites has been excavated extensively. Artifacts were collected from the ground surface of each site, and limited test excavations were conducted at several of the sites. These methods permit the size of each site to be determined, along with the chronology of its occupation.

Although these data have yet to be subjected to systematic analysis, the longevity patterns are highly suggestive. The earliest urban sites, founded in the Late Formative period (green in Figure 5), were situated in the best environmental location: at the edge of the widest expanse of rich alluvial farmland in the entire valley. These sites survived for many centuries, some for nearly two millennia, and it seems clear that their success was due in large part to their location with respect to high quality farmland.

The most rapid and extensive episode of urbanization took place in the Classic period (red), coincident with the conquest of the Yautepec Valley by an empire based at Teotihuacan. Classic period urbanization in this area was generated by administrative needs; these towns probably organized the production and shipment of cotton to the distant imperial capital. When the empire faltered, all but one of the sites was abandoned.

The end of the Classic period cities was followed by a prolonged period of lowered rainfall in central Mexico (Metcalfe et al., 2000; Stahle et al., 2011), during which few cities were founded (yellow). When rainfall increased after AD 1100 (the start of the Aztec period) another wave of urbanization began, but this time the cities were generated by population increase and the growth of local city-states (Smith, 2008). Aztec urbanization came to an end in 1521 with the Spanish conquest of Mexico, although many Aztec cities continued to be occupied and are still thriving cities today (such as Mexico City). While the data are still too rough to draw detailed implications about urban sustainability, they do suggest that a variety of causal factors were involved, from soil quality and rainfall to political dynamics to regional demography. This case also emphasizes the fact that different types of city require separate explanations for their rise and fall.

Figure 4 | Sprawling cities, ancient and modern: Angkor (Evans et al., 2007, pg. 14280) and Phoenix (http://www.mapsandfacts.com/asset/June2010Map.pdf) at the same scale



From ancient cities to urban policy

I have argued here that archaeological research in ancient cities can contribute to a better understanding of contemporary processes of urbanization. If there are policy implications of the kind of work outlined above, I believe they are best expressed indirectly. It seems unlikely to me that policy makers concerned with urban issues will pay much attention to archaeological data on ancient cities. However, if archaeological findings can take their place within a broader framework of comparative knowledge about premodern cities, they can have an indirect effect on urban policy. Policy should be based on knowledge of a wide range of options and cases (including ancient cities), and not limited to a few examples chosen haphazardly. Until that broader comparative framework is constructed, however, archaeology can contribute to research and policy debates to the extent that other urban scholars recognize the field as a relevant and rigorous social science discipline (Smith, 2010b; Smith et al., 2012).

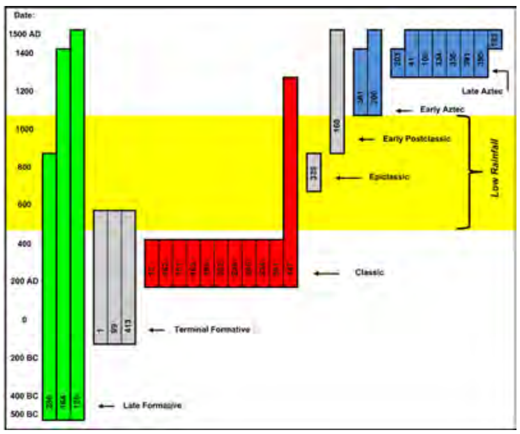
Sociologist Robert Sampson is the leading authority on urban neighborhoods and their effects on individuals and society (Sampson 2009; 2012). His work is widely used in policy

3 For reasons of space I limit consideration here to the sustainability parameter of longevity. Archaeologists are also starting to address other components of (urban) sustainability, including environmental change and social well-being.

circles (Sampson & Morenoff, 1997; Sampson & Raudenbush, 2001), and his perspective is sufficiently broad to incorporate archaeological work on ancient cities. He cites the research of our ASU group in support of a claim for the ubiquity and social importance of urban neighborhoods through history (Sampson, 2012, pg. 437), a claim with policy implications.

By bringing a larger, more diverse sample of cities to the discussion, archaeological research broadens the perspective of urban scholars and improves their explanations of contemporary urban dynamics. I invite the scholars at UGEC and other readers of *UGEC Viewpoints* to take a closer look at ancient cities and see if I am right about their value to research in this area.

Figure 5 | Differential longevity of urban sites in the Yautepec Valley in the Mexican state of Morelos. Each vertical bar is an urban settlement; these are grouped by the time period during which they were founded – see Smith (2006; 2010c) for discussion.



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Ruins of the ancient Mayan city of Palenque, in the jungles of Chiapas, Mexico

Low-Density Urbanism, Sustainability, and IHOPE-Maya: Can the Past Provide More than History?

Vernon L. Scarborough, Arlen F. Chase and Diane Z. Chase

The Dahlem forum on "Sustainability or Collapse" in 2005[1] spawned a variety of regional research groups that now operate under the IHOPE (Integrated History and Future of People on Earth) umbrella. The developing syntheses from these groups are designed to investigate the effectiveness of geographically meaningful units for subsequent cross-temporal and cross-cultural global comparisons. Our group, known as IHOPE-Maya, is composed of approximately twenty researchers working across the Yucatan Peninsula and the Maya Lowlands of Central America (Figure 1) and focuses on the role of coupled human/nature dynamism in the context of an evolving tropical forested civilization (Costanza et al., 2012). The initial charge of IHOPE-Maya was to break down disciplinary divisions and integrate sometimes disparate data sets in a manner compatible with region-wide computational modeling and cultural comparison.

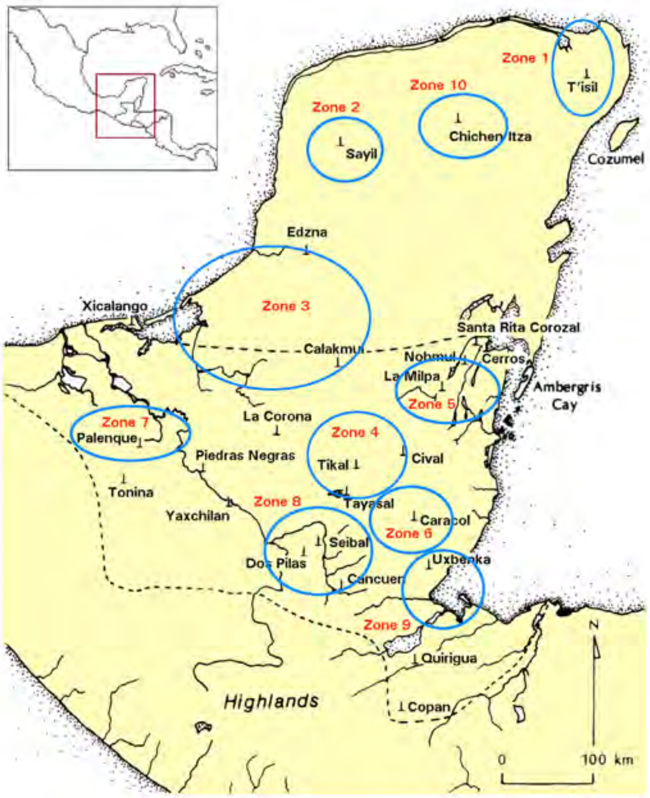
Progress has been made not only in linking specific cultural adaptations to climate forcings and the effects of population growth, but also in understanding the immediate and complex relationships – both short- and long-term – between the greater natural environment and society. We are especially sensitive to the renewed role of culture change and how our knowledge of past ecological systems has now evolved into a subset of our global cultural systems. With respect to the ancient Maya, determining the degree to which they successfully altered their environs – or regionally damaged it – within the constraints of their technologies and innovations has great potential for assessing present-day societal adaptations.

Maya urbanism

Although there are several facets to our IHOPE-Maya work, an intriguing aspect evolving from recent field studies at Tikal, Guatemala (Scarborough et al., 2012) and at Caracol, Belize (A. F. Chase et al., 2011) – two of the preeminent "cities" in the Maya area at AD 700 – is the kind and degree of urbanism now identified.

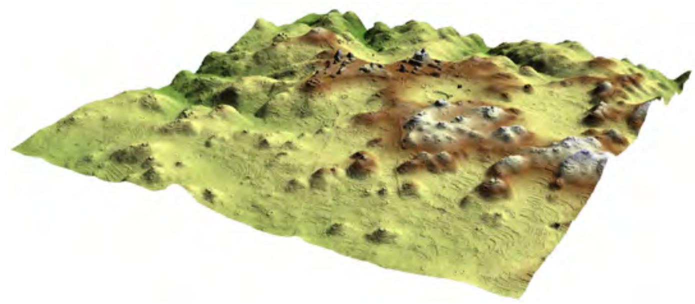
1 The June 2005 IHOPE-Dahlem conference in Berlin, Germany assembled an interdisciplinary group of 40 top researchers from a range of natural and social science disciplines, with the goals of identifying how humans have responded to and impacted their environments over millennial, centennial and decadal scales as well as providing a glimpse of the future of the global human-environment system. Results from IHOPE-Dahlem are now published in the book, Sustainability or Collapse? An Integrated History and Future of People on Earth, from MIT Press (Costanza et al., 2007).

Figure 1 | Map of Maya area showing locations of zones under investigation by IHOPE-Maya; Tikal centers Zone 4 and Caracol centers Zone 6 *(courtesy of IHOPE-Maya)*



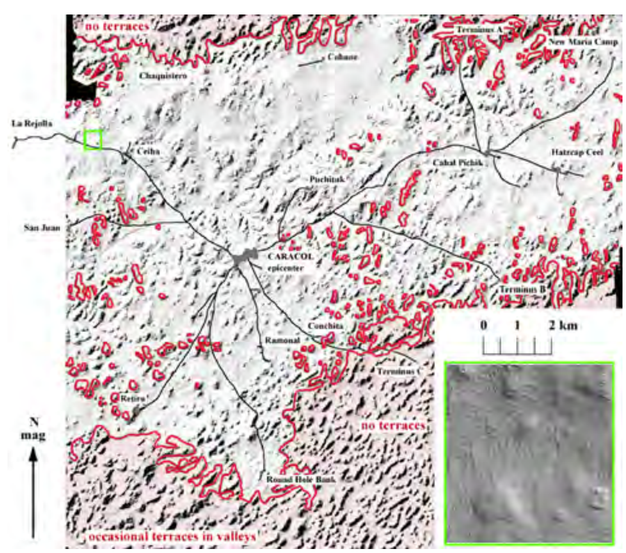
Given Paul Sinclair's commitment to the "Urban Mind" project (http://www.arkeologi.uu.se/Forskning/Projekt/Urban_Mind/Introduction/) within the IHOPE mission, a focus on this topic seems appropriate. Drawing from the work of Roland Fletcher and his colleagues at Angkor, Cambodia (Fletcher, 2009), it has become clear that the Maya practiced a form of "low-density urbanism." Scarborough has argued that ecological rules drove this settlement pattern at the outset – that is, the diversity of plants and animals in the tropics remains the greatest on the planet, but the incidence or richness of any one species in any one patch or microenvironment is highly limited. Unlike the potential for centralized urbanism in semiarid settings based in part on the concentration of several domesticates – vast wild and "natural" wheat or barley stands or gregarious herd animals like wild cattle, sheep, or horse (all identified with the first Old World experiments in domestication) – the Maya adapted to a wet-dry tropical forest that encouraged population dispersion for harvesting and exploiting local resources to make a living. Although Maya rapidly gravitated toward centers of control for greater societal order, their definition of "city" was always constrained by their environmental reality.

Figure 2 | 2.5D LiDAR image of central Caracol looking northwest *(courtesy of Caracol Archaeological Project)*



Digital aerial imagery from Caracol, specifically Light Detection And Ranging (LiDAR), has accented a vast landscape covered with dispersed, but continuous, residential groups, civic architecture, and agricultural terracing (Figure 2) – all within a single Maya city (A. F. Chase et al., 2011; 2012). The data confirm what was implied by years of settlement survey and excavation – that Caracol was a huge ancient city spread over almost 200 square kilometers of landscape. The imagery also shows the intense landscape manipulation that was necessary for sustaining the city's inhabitants as well as the integration of the city through a series of radial roadways (Figure 3). Only the scale of area covered by the LiDAR survey provides partial edges to an otherwise "boundary-less" settlement.

Figure 3 | Caracol road system and area of continuous agricultural terracing overlaid on the LiDAR Digital Elevation Model of the site. The anthropogenic landscape can be clearly seen in the agricultural terracing evident in the inset. The Caracol low-density urban adaptation was successful for approximately 500 years *(courtesy of A. F. and D. Z. Chase).*



At Tikal, settlement work suggests similarly subtle density drop-off zones as one leaves the civic center (Puleston, 1983). However, based on the new work at Caracol, the boundaries between urban centers may prove yet more subtle. Given their scale and concentration of monumental architecture – from pyramids and palace-like structures (Figure 4) to the surface area of plaza space and reservoir volumes as well as their manifest of quality and quantities of other artifactual wealth, it would be imprudent to call Maya cities decentralized. Nevertheless, the scattered character of their populations and associated resources does identify the sprawl of low-density urbanism. As has been noted previously (D. Z. Chase et al., 2011), the population density of the ancient Maya is well within the range of contemporary urban and suburban populations.

What Tikal adds to the recent literature is the complex infrastructure that these "centers" required. To accommodate the many laborers, visitors, and residents occupying or at least frequenting the heart of a Maya city required "monumental" maintenance investments as well as functional ends put to a predictable water supply (Figure 5). The latter is now well-defined as a waterworks system at Tikal and was no doubt highly developed in other urban aggregates (Scarborough et al., 2012; Scarborough & Gallopin, 1991).

Today?

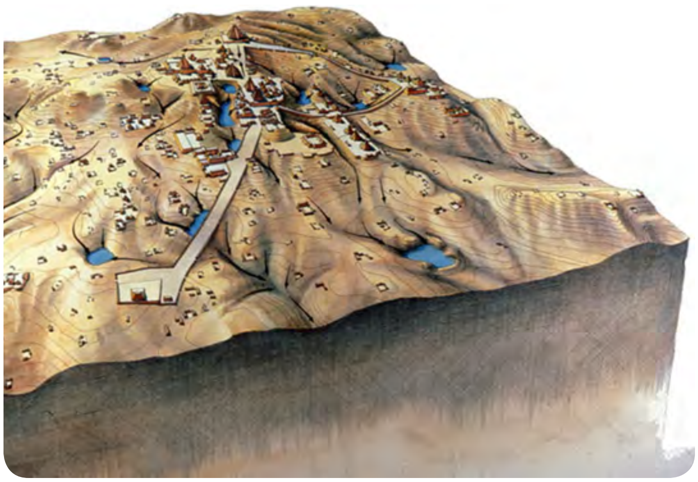
So what, then, can the ancient cities of the Maya realm introduce to our perceptions of a vibrant urban setting today? Given cultural and technological differences – to say nothing of the disadvantages of living in a fragile tropical environment – how can the past be of any real aid in assessing our urban plans for the future?

Perhaps our Western technologies are now finally poised to revisit a notion of urbanism reclaimed from the past. Maya centers and their hinterlands are revealing extensive roadways beyond the core zones of specific sites – apparent at cities like Caracol, Coba, and Chichen Itza. And, when contextualized by the amount of time and energy invested by the Maya in their ancient calendar system – surely a set of scheduling devices for economic purposes as much as for any political or ideological end – cities had a highly organized and rapid interconnectivity. This kind of integration was not limited to their cities, as the Maya hinterlands were inextricably joined by way of a "high-density ruralism," allowing for rapid and efficient linkages between those small communities and the marketing advantages of both established and emerging "low-density urban centers."

The ancient Maya notion of settlement and hinterland interdependency evolves from an economic organizational foundation based on "resource-specialized communities" or the concept that many rural villages or hamlets tended to specialize in at least one economic resource and then circulate that resource through marketplaces; in Maya low-density cities, urban residential households mimicked the diverse specialization found in the hinterlands. Solar markets that were embedded in different venues and communities throughout the Maya landscape ensured predictable access to specific economic items for any household (Scarborough & Valdez Jr., 2003; 2009). Some communities might well accommodate certain fundamental political or ideological institutions pervasive in Maya culture, like the ballgame and the ballcourt or types of low-cost astronomical observation

Figure 4 | Photo of Tikal looking north across the palaces of the central acropolis to Temple 1 *(courtesy of IHOPE-Maya; date unknown)*

Figure 5 | Graphic showing central Tikal and its reservoir system (*courtesy of V. Scarborough*)



architecture; such small community investments likely resulted in periodic visitations and associated market activity by neighboring villagers. The resource(s) in which a community might specialize was broadly defined and tied to the needs of the greater district of interdependent communities (Scarborough & Valdez Jr., 2009).

A high-density ruralism connected to a world economy could well redefine our highly nucleating idea of city, providing an ancient analog to the contemporary notion of a "blue-green city."

Because of the difficulties in concentrating or storing organic remains in a tropical environment, highly centralized urban supply chains were likely less effective, although this did not preclude long-distance trade or production in foodstuff by the Maya. When coupled with waterborne disease frequently spiking with dense urban aggregates, the low-density urbanism of the greatest "cities" was complemented by the "high-density ruralism" of the hinterlands. For some time, the health benefits derived from the dispersed settlement pattern practiced by the ancient Maya have been known (Chase et al., 1990; Drennan, 1988).

Could a model for our mega-cities be drawn from the Maya example of urbanism? Recently, Seto et al. (2012) lament the notion of a rural-urban polarity in our present-day assessments of cities, especially as resources are frequently located in a geographical mosaic of localities. Perhaps this reality and its prospects for future land-use harvesting and expansion might draw on a version of the outlined Maya model. In this scenario, the internet and the cultivation of market-driven co-operatives based in rural settings are the loose equivalent of the roads and calendars (the internet) and resource-specialized communities (the cooperatives) of the Maya, allowing the rapid pricing and subsequent movement of goods and services from otherwise isolated locations away from today's urban hubs.

While the virtues of mega-cities continue to be extolled (Glaeser, 2011; Kennedy, 2011), clearly contemporary cities do provide the concentrated labor and services driving the world economy – but at what price? Urban poverty is frequently more severe and pervasive than subsistence living in rural settings, and notions of well-being in a favela or ghetto can surely be questioned. We are not advocating a Rosseau-like return to a hinterland nature, but we are suggesting that a high-density ruralism connected to a world economy could well redefine our highly nucleating idea of city, providing an ancient analog to the contemporary notion of a "blue-green city." This will require cities to "open up" and work to improve inter-city transport of people, things, and ideas. Perhaps the European landscape is positioned to logically accommodate several of the Maya principles. Rail traffic and the internet are the roads and scheduling conduits pre-adapted for this kind of expansion and cultivation of resource specialized communities.

Nothing in this approach is new and in the Maya case it is a mere 2000 years old. However, a closer review of what has transpired in the deep past is as appropriate as fixating on the present order of our world and limiting our options to what has been identified as "urbanism" over the last century. The world is changing and we need to interrupt our sometimes romantically constructed path dependency associated with a restricted view of urbanism before the current myth of the sublime nucleated megacity is covered by waves of a sea level advance or the congestion of disease vectors. This is not an indictment of all present-day cities, but instead just another dimension to assess our future.

Acknowledgements

Our discussion here has very much benefited from a series of seven multi-day meetings of the IHOPE-Maya group beginning with our first assembly in January 2009 at the School of Advanced Research in Santa Fe, New Mexico. The work of IHOPE-Maya members will be showcased in a 2013 volume titled The Resilience and Vulnerability of Ancient Landscapes: Transforming Maya Archaeology through IHOPE (edited by A. F. Chase and V. Scarborough) that is being published by the Archaeology Section (AP3A) of the American Anthropological Association.

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The modern high-density city of Cochabamba is located at c. 2600 meters above sea level in the Bolivian Andes, spreading out over former prime farmland. In the late pre-Columbian period the valley of Cochabamba formed one of the main agricultural production zones of the Incas, providing the empire with maize.

Investigating Urban Experiences, Deconstructing Urban Essentialism

Christian Isendahl

Archaeological research demonstrates that urbanism as a global phenomenon has a considerable time-depth (see for instance Smith, 2003; Posey, 2006; Marcus & Sabloff, 2008). On most continents, people have for more than a millennium organized settlements in ways that we in some sense can recognize today as distinctly urban. Research also shows that different historical ecological pathways have created considerable spatial diversity and temporal variation in urban systems, and yet this is overlooked in contemporary urban scholarship. Although urban scholars and planners often reference the past, the scope of the frame of reference is spatially and temporally limited in relation to the wealth of the data. Isendahl & Smith (2012) suggest that urban scholars and planners should draw from as wide a range of cases and models as possible when considering options to inform the development of sustainable and resilient future cities. In this view, urban archaeologists have a distinct role to play in broadening the frame of reference, complementing recentist (Sluyter, 2010) biases.

A prerequisite to connect urban cases of the distant past with current sustainability concerns entails a kind of basic understanding that past cities are not simply idiosyncratic and historic — and therefore irrelevant when viewed from current cultural, social, political, economic, demographic, and environmental contexts. In parallel to the formalist/substantivist debate within economic history on the antiquity of market mechanisms[1], a formalistic stance to cities as a universal, long-term phenomenon suggests that these are comparable throughout human urban history, not least in terms of associated challenges and opportunities. Historical ecologists often argue that the present is contingent on the past (Balée, 2006; Crumley, 1994),

1 Neoclassical economic thought poses a formalist universalist model of the distinction between pre-modern and modern economies as one of degree, while substantivists, following Polanyi, find it a difference in kind (see Kepecs, 2005, pg. 118)

a view that in some sense reverberates profoundly with Andean cognitions of 'the past' as something that is 'in front of us,' (i.e., it is known and can be seen), and in contrast to the common Western conceptualization of the past as time we have 'left behind us' (Isendahl, 2012a, pg. 9). This is a perception of the past that also resonates within an applied approach to urban archaeology. Although the archaeological record of cities cannot provide blueprints for current planning needs and priorities, it does offer a pool of experience of strategies, successes, and failures of urban planning to draw from. For instance, the archaeological record can help elucidate which factors build long-term urban resilience and which introduce vulnerabilities to stress factors (Heckbert et al., Forthcoming). The nature of archaeological data is also particularly suitable for tracking the effects of slowly changing variables for the long-term resilience capacity of urban systems (see Carpenter et al., 2001).

Outlining an applied urban archaeology in its problem-solving sense, Sinclair and colleagues (Forthcoming) argue for the potential of archaeology to actively contribute the insights that an understanding of long- and short-term outcomes of past urban planning strategies offers to develop new strategies that address the challenges of uncertainty that global environmental change presents. Perhaps the most imminent challenge to put such visions into any practical effect involves reaching out to urban scholars in the planning sector with the broader implications of crucial data. At the individual level, it requires archaeologists to put the insights gained from research in concrete form and publish in non-disciplinary jargon in journals and media consulted by urban planners. But, it particularly requires that archaeologists be in agreement with the conditions of urban planning and the current challenges of urban development, and at the same time, for planners to have a sensitive ear to the relevance of deep-time perspectives and broad frames of reference for these issues. High-profile trans-disciplinary research projects and networks have key roles to play in this process.

The Urban Mind

Based at the Department of Archaeology and Ancient History at Uppsala University, Sweden, and coordinated by Paul Sinclair, The Urban Mind was a two-year collaborative project formed to initiate a broad exploration of the diversity of urban expressions, integrating perspectives from the humanities, social sciences, and natural sciences with the ultimate goal to develop research ideas that may be further pursued to inform planning for sustainable urban systems. Linked to IHOPE (Integrated History and Future of People on Earth) and WHEN (the World Historical Ecology Network established at Uppsala by the author in 2010), The Urban Mind was supported by an Idea Development grant from Mistra (the Swedish Foundation for Strategic Environmental Research) over the period 2008-2010 and brought together nearly 40 scholars at Uppsala University, Stockholm University, and The Royal Institute of Technology in Stockholm as well as associated colleagues from around the world to discuss issues of urban form, metabolism, resilience, governance, and environmental interactions. Project activities, including excursions, workshops, and research, ultimately resulted in the edited volume *The Urban Mind: Cultural and Environmental Dynamics* (Sinclair et al., 2010). In collaboration with colleagues in Botswana, Kenya, Madagascar, Mozambique, South Africa, and Zimbabwe, we are currently detailing future research within an Urban Minds (note the plural) project initiative, at least partly set to explore aspects of how a better diachronic and synchronic understanding of the diversity of cognitive dimensions of city space can contribute to an urban land use planning that builds food security in southern and eastern African cities.

> Urban essentialism has destructive effects by limiting options for food security, protracting energetically costly food systems, and institutionalizing vulnerabilities in urban social-ecological systems.

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Street-side market in Kampala, Uganda

Urban essentialism undermining food security

Perhaps one of the most intriguing themes — and possibly most fundamental and far-reaching — brought up for critical discussion is how deep-rooted the modernist perception of urban essentialism has been over the last century, dominating and streamlining how we tend to think about urbanism as a largely uniform type of social formation, even in the pre-modern past. The notion of urban essentialism, of urban livelihoods as qualitatively distinct from rural ones, gained legitimacy within the Chicago School of urban sociology (e.g., Wirth, 1938; Woolston, 1912), and largely remains standard in common sense understandings of cities today. Rhodes et al. (2012, pg. 13527) define social essentialism as 'the belief that certain social categories (e.g., gender, race) mark fundamentally distinct kinds of people. Essentialist beliefs have pernicious consequences, supporting social stereotyping and contributing to prejudice.' The form of urban essentialism particularly addressed here is the dogmatic separation in modernist thought between city folk/townspeople and agriculturalists, between the urban and the agrarian (see also Barthel & Isendahl, 2012; Isendahl, 2010; 2012b).

In a sense, The Urban Mind Idea Development project formed a process of starting to unlock a mental block in terms of intuitively set minds that limited our understanding of the diversity of the constitution of cities. On the basis of archaeological and historical data, we have argued that urban essentialism has destructive effects by limiting options for food security, protracting energetically costly food systems, and institutionalizing vulnerabilities in urban social-ecological systems (Barthel & Isendahl, 2012). Locked into a modernist essentialist understanding intrinsically coupled and reciprocally reinforced by space/time compression (i.e., the socio-economical processes that subsidized by fossil-fuels reduce the significance of space and accelerate the pace of time [Harvey, 1990]), globally, early 20th century urban planning found proximal food sources obsolete in urban systems. A century later, it has formed a deep-rooted prejudiced understanding of urban social-ecological systems that for instance is reflected in the standard analyses of urban metabolism that conceptualizes foodstuffs solely as material that flows into cities as centers of consumption. While this is true in most cases today (but consider for instance the situation in Havana, Cuba [Altieri et al., 1999]), a one-way flow pattern from external sources was not commonly a characteristic of urban metabolism in the past.

A particularly lucid example of more complex flows of foodstuff materials is the Classic Maya lowland cities of the first millennium AD, in today's southern Mexico, Guatemala, and Belize (Graham, 1999a; 1999b; Isendahl, 2010; 2012b; Isendahl & Smith, 2012; Scarborough et al., 2012). Classic Maya cities conform to a hybrid type of cities that Roland Fletcher (2009; 2012) labels 'agricultural-based low-density cities.' A straightforward definition of this term is that settlement structures are relatively spread-out in the landscape, inter-mixing 'traditional' urban land uses with green areas and agricultural production zones such as gardens, orchards, infields, and agro-forestry reserves. In addition to the Classic Maya, this phenomenon has been well-attested in research from cities of the Khmer Civilization in Southeast Asia (Fletcher, 2009; 2012). Once acknowledging the existence of such conceptual anomalies as 'agro-urban landscapes' (Isendahl, 2010; 2012b), however, we find that urban settlement agriculture is quite a widespread phenomenon in the archaeological and historical record. In some cases (such as Classic Maya cities), agriculture is a long-term integrated part of the urban form, in others (such as Constantinople), fields and gardens are responses to different kinds of periodic and reoccurring stresses to the urban food supply system (e.g., Barthel & Isendahl, 2012; Isendahl, 2012b; Isendahl & Smith, 2012).

The body of evidence indicates that agricultural production cannot comfortably be regarded as 'the antithesis of the city' — as common essentialist-flavored understandings of urbanity seem to suggest — but is in many cases a fully integrated urban activity, viewed at the long-term and global scales (Barthel & Isendahl, 2012; Isendahl, 2012b). A good understanding of the diversity of urban systems in the past offers a broad pool of options to consider for urban planners that must not go unnoticed. Identifying and questioning remnants of limiting modernist urban essentialism in urban scholarship and planning has led us to argue that there is a need for an alternative conceptualization that reimagines the city as a place where food is produced (Barthel & Isendahl, 2012).

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Are City-Based Emissions Trading Schemes Efficient Instruments for Reducing Local GHG Emissions?

Benoit Lefèvre and Gautier Kohler

With more than half the world's population living in urban areas, the environmental impacts of cities have become an integral focus of urban policies. Poor urban air quality and the issue of climate change have pushed local governments to implement environmental policies that will reduce emissions from various sources. Originally developed in the 1990s to decrease local pollution, local Emission Trading Schemes are now emerging as promising cost-efficient instruments for achieving local green house gas (GHG) emissions reductions.

Traditionally, regulations have been largely preferred over other types of policy instruments to address environmental issues. They have been used in Western cities since the end of the 17th century (e.g., in conjunction with water and sanitation programmes) and are favoured by industries, as they benefit from the power of negotiation in the legislation process. However, regulations have been criticised for their low economic efficiency and poor environmental performance.

Incentive-based economic policy instruments have recently been developed and implemented as alternatives to traditional Command and Control (C&C) mechanisms. The two principal economic policy instruments are emission taxes and Emission Trading Scheme (ETS) programmes. Emission taxes possess many advantages including efficiency, simplicity and the capacity to generate revenue. Nevertheless, fundamental disadvantages – including political unpopularity, an absence of a guaranteed emission reduction and the potential for distributional inequity – have limited their implementation. ETS programmes[1] have been promoted for their cost-efficiency and guarantee of emissions reductions. By establishing a market for emissions, in which participants can trade allowances, it enables cleanup costs to be shared more evenly in an optimal manner among different sources, taking into account their specific context. Nevertheless, in theory, cost-effectiveness can only be achieved if transaction costs

1 Emissions trading or cap-and-trade is a market-based approach used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants. A central authority (usually a governmental body) sets a limit or *cap* on the amount of a pollutant that may be emitted. The limit or cap is allocated or sold to firms in the form of emissions permits which, represent the right to emit or discharge a specific volume of the specified pollutant. Firms are required to hold a number of permits (or allowances or *carbon credits*) equivalent to their emissions. The total number of permits cannot exceed the cap, limiting total emissions to that level. Firms that need to increase their volume of emissions must buy permits from those who require fewer permits. The transfer of permits is referred to as a trade. In effect, the buyer is paying a charge for polluting, while the seller is being rewarded for having reduced emissions. Thus, in theory, those who can reduce emissions most cheaply will do so, achieving the pollution reduction at the lowest cost to society.

Table 1 | Key design parameters of city-based Emission Trading Schemes

	Chicago	Los Angeles	Santiago	Tokyo
Year of Implementation	**1999**	**1994**	**1994**	**2010**
Policy Goal	Attainment of state and national Air Quality Standards	Attainment of national and state Air Quality Standards	Attainment of national Air Quality Standards	Climate change mitigation initiative
Environmental Objectives	12% reduction of ozone precursors	70% reduction of ozone precursors	64% reduction of aggregated PM10 emissions, compared to levels prior to the programme 50% reduction of NO_x emissions (since 2008)	25% reduction of GHG emissions, compared to the 2000 level, by 2020
Overlapping Regulations	Federal Hazardous Air Pollutants (HAP) regulations National Air Quality Standards Best Available Technology	National Air Ambient Quality Standards Best Available Technology	National Air Quality Standards Supreme Decree 32 on emergency periods	
Pollutants Targeted	Volatile Particulate Matter (PM)	Nitrogen and sulphur oxides (NO_x and SO_x)	Particulate matter (PM10) (since 1994) and Nitrogen Oxide (since 2008)	Energy related carbon dioxide (CO_2)
Stationary Sources Affected	179 participants covering major stationary sources	392 participants covering a multi industry sector accounting for 65% of the region's stationary emissions	Stationary combustion sources accounting for 7% of total PM10 emissions	1,400 facilities (buildings/ factories) covering industrial and commercial sectors, accounting for 40% of industrial and commercial CO_2 emissions
Mobile Sources Affected	None	Partly introduced but never implemented	None	None
Compliance Period	Permanent	Annual	Permanent	5 years
Compliance Reconciliation Frequency	Seasonal	Annual	Annual	5 years
Initial Free Allocation	Grandfathering	Grandfathering	Grandfathering	Grandfathering
Provisions for Newcomers	No allowance allocated – offset ratio of 1:1 for small emitters and 1:3 for large emitters	HI/LO reserve Private auctions for others	No credits allocated Offset ratio of 1:2	Reserve for new entrants free of charge Strict performance standards applied if certain energy saving measures are not adopted
Baseline	Maximum emissions over historic period with adjustment for voluntary over compliance reduction	Maximum emissions over historic baseline period	Emission capacity	Average of actual emissions over historic period
Nature of the Cap	Implicit[2]	Absolute and declining	Implicit	Absolute and declining
Temporal Flexibility	1 season banking No borrowing	No banking No borrowing	No banking No borrowing	No banking No borrowing
Spatial Trading	Unrestricted	Two trading zones	Unrestricted	Unrestricted
Nature of Emissions Trade	Permit-based	Permit-based	Credit-based	Permit-based
Emissions Monitoring	No homogenous methods No guidelines established prior to the implementation	Continuous Emissions Monitoring Systems (CEMS) obligatory for two thirds of sources, other less strict methods Methods established by the regulatory agency	Emission capacity	Energy consumption measured and calculated by gauges, bills and receipts Guidelines established prior to system implementation Fixed emission factor is used
Reporting of Permit Transactions	Non-mandatory	Non-mandatory	Mandatory for transaction approval[3]	Non-mandatory
Monetary Penalties	Not directly	Yes Actual sanctions decided on a case-by-case basis	Ranges from US $4.5 to $90,000 Actual sanction decided on a case-by-case basis	Up to ¥500,000 Automatic penalties

Source: Kohler & Lefèvre (2011)

2 Chicago C&T absolute emissions level was determined during the allocation process. The higher the emissions total, the larger the overall cap.

3 Transactions require approval by the regulatory agency; penalties and actual sanctions are decided on a case-by-case basis.

are marginal and if the distributed allowances have a marketable value in the eyes of participants.

Several ETS programmes have already been implemented on different scales. While regional and national ETS projects have been heavily publicised and examined abundantly in the literature, little attention has been paid to city-based ETSs.

In the early 1990s, only a few cities had developed their own programmes to curb local pollutant emissions and in so doing were among the pioneers of implementing market-based environmental policy instruments. Twenty years later, new local emission markets are emerging as climate change policy instruments. In 2010, the Metropolitan Government of Tokyo launched the world's first Cap and Trade (C&T) programme at the city level, targeting energy related CO_2; other such initiatives are currently under discussion in China's metropolises.

Here we compare four existing city-based ETS programmes: three that target local pollutants – in Chicago, USA; Los Angeles, USA; and Santiago de Chile; and one targeting greenhouse gases – in Tokyo, Japan; in order to identify common and distinguishing features, and elements of success. Rather than presenting in detail the analysis of each local ETS, which would be beyond the scope of this article, we focus on the lessons which can be drawn from the comparison. The results of the comparative analysis are summarised in Tables 1 and 2.

Evaluation of ETS programme performance

Although the objectives may differ slightly from one programme to another, performance is evaluated according to the same three criteria:

a. **Achievement of the environmental objective.** This is evaluated by comparing actual emissions with the initial expected air quality target. The stringency of the objective is not discussed here.

b. **Degree of market development.** The volume traded, the expiration of non-used credits, the price volatility as well as the market structure are the main factors considered.

c. **Degree of cost-effectiveness.** This criterion is more controversial, as it requires the comparison of the environmental results achieved by the ETS programme with the potential results of a Command and Control method that could have been implemented instead. Thus, our assessment is based on the existing literature. We discuss the results of several authors, who have tested different hypotheses. We do not assess the Tokyo ETS because it has not been implemented for a sufficient period of time to allow evaluation of its performance.

Table 2 | Summary of the ETS programme performance

	Santiago	Chicago	Los Angeles
Environmental Objective	**Achieved**	**Achieved**	**Achieved**
Level of Market Development	**Low**	**Low**	**High**
Volume of Trade	Low	Low	High
Trading Price	Not communicated publicly	Stabilised at a much lower level than predicted Conducive to trade	High volatility between compliance periods Conducive to trade except during energy crisis
Expired Credits	40% (in 2006), 17% due to non-use	40% to 60%	25%
Compliance Rate	Average: 75%	Over 90%	Over 90%
Regulation Overlaps	Significant because of emergency periods	Significant (30% of emissions reduction was attributed to other regulations)	Marginal
Cost-Effectiveness	**Limited market incentives provided (compliance to C&T obligations was justified by exogenous reasons)**	**Limited market incentives provided (lack of permit scarcity)**	**The capacity of the programme to achieve greater or equal environmental objectives remains controversial**

Source: Kohler & Lefèvre (2011)

The implementation of three city-based C&T programmes provides evidence of the general pitfalls and benefits of an ETS. All programmes have achieved and sometimes exceeded their environmental targets (Kohler & Lefèvre, 2011). However, the Illinois and Chilean markets have not yet reached maturity as prices are kept low while the amounts of unused credits remain high.

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In both of these programmes, the market participation of covered sources is marginal, and the improvement in air quality is attributed to exogenous factors. The trading activities registered under the Californian market are much more significant and are a testament to the key role attributed to the C&T programme in the region's environmental policy (Kohler & Lefèvre, 2011).

Despite this, the cost-effectiveness of the programmes compared to other policy options remains controversial. However, the last ten years of experience has helped authorities and participants to reduce transaction and administration costs. As a result, trading volume has increased over time, highlighting the importance of 'learning by doing', which is helping to fine tune the local ETS programmes (Kohler & Lefèvre, 2011).

Key elements to ETS success

The city-based ETS programming developed in the 1990s must be evaluated as pilot projects in the implementation of market-based environmental policy instruments. While their cost-effectiveness remains controversial, lessons have been learnt and solutions to technical issues have been successfully provided. All programmes have, thereby, contributed to improving the inventory of sources and emissions. They have also encouraged sources to internalise the cost of pollution in a more flexible manner.

We highlight several points that require special attention in order to improve the functioning of the market.

Flexibility and predictability

Any C&T system can be subject to exogenous factors that may disturb the correct functioning of the overall programme. When the energy crisis occurred in California, the power plant had to increase its electricity generation, which meant that permit prices shot up in a few months. When confronted with such an event, a system should be able to respond quickly in order to absorb smoothly the external shock. In 2001, the Los Angeles C&T regulatory agency amended the programme and succeeded in temporarily removing the power plant from the scheme, thereby increasing the credit availability in the market. As these kinds of disturbances are very difficult to predict, it is essential that policies allow a certain degree of flexibility.

The flexibility comes first from the legal structure adopted by the programme. Similar to a national or regional ETS, the status of tradable units should be clearly defined so as to avoid the issue of property rights. C&T permits are not considered property rights and the regulatory agency should reserve the right to suspend or terminate credits. These specifications must be well defined in the rules and relevant legal terminology, so that the credit definition is clear.

Predictability and consistency are also important principles for an effective ETS (Schreifels, 2007). There is a dire need for changes to programme rules to be carried out through transparent procedures, and to allow sufficient time for industries to adapt to such changes.

Accountability and transparency

Successful programmes have several features in common, including solid, robust and transparent accountability, strict rigorous enforcement and a limited but effective governmental role. Emissions measurements must be accurate, and measurement methodologies well-defined, prior to the implementation of the programme. Information transparency is essential for trading activities and emissions reporting because it builds confidence amongst all stakeholders and ensures a better compliance rate (The World Bank, 2010). All information must be centralised by the regulatory agency, which should also apply strict and predefined enforcement rules (Nishida & Hua, 2011).

Environmental integrity

The allocation of allowances was considered as the most critical challenge faced by C&T developers. In the local pollutant programmes, allocations were based on the maximum annual emissions figures for each participant over certain historic periods. This grandfathering methodology, based on maximum rather than average past emissions was justified by the proposal of political constraints. It was argued that an average emission method would jeopardize actual economic output and future growth opportunities. The grandfathering method also has the advantage of providing incentives to sources for assessing and reporting their emissions (Montero et al., 2002). However, it has also been shown to encourage false reporting, particularly when the authorities have a poor historic record of sources and emissions (Evans & Kruger, 2006). The environmental integrity of a policy also depends on the rate of compliance. Monitoring and enforcement are the two most important design issues for providing enough incentives to ensure a high degree of compliance.

Additionality and complementarity

Local market-based instruments are usually part of a broader set of environmental policies set up on a different scale. The interaction between these policies can have significant consequences on the cost-effectiveness of C&T programmes. City-based programmes must be compatible with other state and federal regulations to ensure that the programme is enforceable and to guarantee its environmental integrity. Overlaps with other regulations may be a cause of over-allocation, which can reduce the effectiveness of the C&T market incentives given to sources to reduce their emissions.

This comparative analysis also shows that most of the issues raised in local ETS programmes could be tackled during the development phase. Appropriate design parameters alone are not sufficient to guarantee programme success. Proper management practices are equal determinants to guarantee programme success. Therefore, sufficient time and resources must be made available to discuss important matters among all stakeholders such as target achievability, agreement on measurement methodologies and the development of an appropriate legal framework that institutionalises the relevant instruments. Stakeholder participation at this stage is crucial, as it builds the necessary confidence among the sources and public regulators. Capacity building programmes must be organised to introduce companies to emission trading concepts, and to acquaint regulatory agency staff with automation systems. While the development costs of an ETS seem much higher than that of C&C policy instruments, such expenditure is nevertheless essential to establish a strong and common basis to ensure good programme performance.

During the implementation phase of programmes, market activities must be closely monitored so that the regulatory agencies have sufficient time to adopt measures in situations where exogenous factors disturb the proper functioning of the market.

Final comments

Local ETSs can provide relevant solutions within climate change mitigation programmes. Such schemes can be used as complementary instruments to national programmes that target energy intensive industries. Its demand side approach also enables final customers to be held directly responsible for their behaviour. The successful development of these schemes could, therefore, provide cities with a powerful instrument to address their growing environmental problems. It would also underline the growing awareness of the crucial role that urban areas can and must play in reducing greenhouse gas (GHG) emissions. But, for cities to engage in such local ETSs, deeper decentralization, additional power and competencies for cities to increase their capacity to act are often needed.

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Mexico City

Mexico City in the 21st Century: Population Dynamics and Policy Responses

Gary Sands and Laura A. Reese

In 1980, many observers decried the 'disastrous overdevelopment' of Mexico City (Davis, 1994). The Federal District (the legal limits of the capital city), added two million new residents in each of the two previous decades, and growth was expected to continue unabated. The rate and amount of growth in the suburban portion of the urban area were even greater. Population of adjacent areas of the State of Mexico grew by five million new residents between 1960 and 1980, a tenfold increase. The Mexico City Metropolitan Area had the potential of becoming the largest urban agglomeration in the world.

City and suburban population growth was fueled by rural migrants settling on the periphery in self-built housing. The average household size in 1960 was 5.4. The provision of basic services lagged far behind the rapidly spreading footprint of the urban area. Congestion and environmental degradation (particularly aquifer depletion and air pollution) continued to increase along with the population.

While the Mexico City Metropolitan Area continues to grow and to experience a host of problems, the vision for its future is much less pessimistic than it was 30 years ago. Today, population growth has slowed (Table 1) to the point where the population of the Federal District is essentially the same as it was thirty years ago in 1980.[1] Decreases in birth rates nation-wide have eased growth pressures. Internal migration to the capital has actually shifted to a net out-migration. This relative population stability has allowed the District government to address some of the undesirable side effects of rapid urbanization. The Mexico City government has adopted a multi-faceted plan to mitigate the effects of climate change (Secretaría del Medio Ambiente del Distrito Federal, 2008). Air quality has improved partly as a result of the continued development of more efficient and less polluting transit systems. Water resources are somewhat more secure[2]. Housing quality has improved on a number of measures.

Although the total population of the Federal District has seen little change since 1980, the city continues to face development-related issues. Rising real incomes and the expansion of the middle class have contributed to exponential growth in automobile ownership, and altered the types of housing and commercial

1 Adjacent areas in the State of Mexico have continued to experience significant growth.

2 See Calidad del Aire en La Ciudad de México: Informe 2011 (Cuidad de México, 2012): http://www.sma.df.gob.mx/sma/links/download/biblioteca/flippingbooks/informe_anual_calidad_aire_2011/

Table 1 | Population trends (in millions)

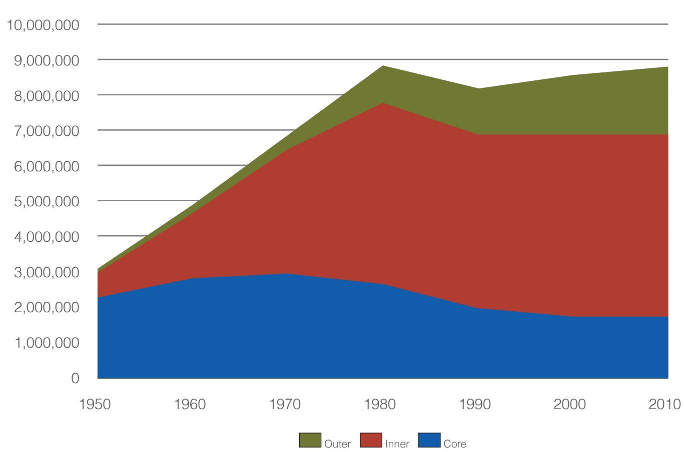
	Federal District	Metropolitan Area	Percent Suburban
Population 1950	3.050	3.136	2.7%
Population 1960	4.871	5.381	9.5%
Population 1970	6.874	9.211	25.4%
Population 1980	8.831	14.419	38.8%
Population 1990	8.236	15.048	45.3%
Population 2000	8.605	18.397	53.2%
Population 2010	8.851	20.107	56.0%

Source: Instituto Nacional de Estadística y Geografía (INEGI)

development sought by the market. Declining average household size has generated demand for more housing. The effects of global deindustrialization and the rise of the services sector have contributed to land-use changes (Garza & Sobrino, 2009). Before considering how these contextual factors have influenced the population distribution within the Federal District, we first outline some of the changes that have occurred over the past two decades. Three different geographic scales will be considered:

- delegación (borough or district level) - there are a total of sixteen within the Federal District
- colonia (community) - a subdivision of a delegación
- AGEB (Area General Esistico Basico or neighborhood) - the smallest statistical reporting unit, equivalent to a US census tract

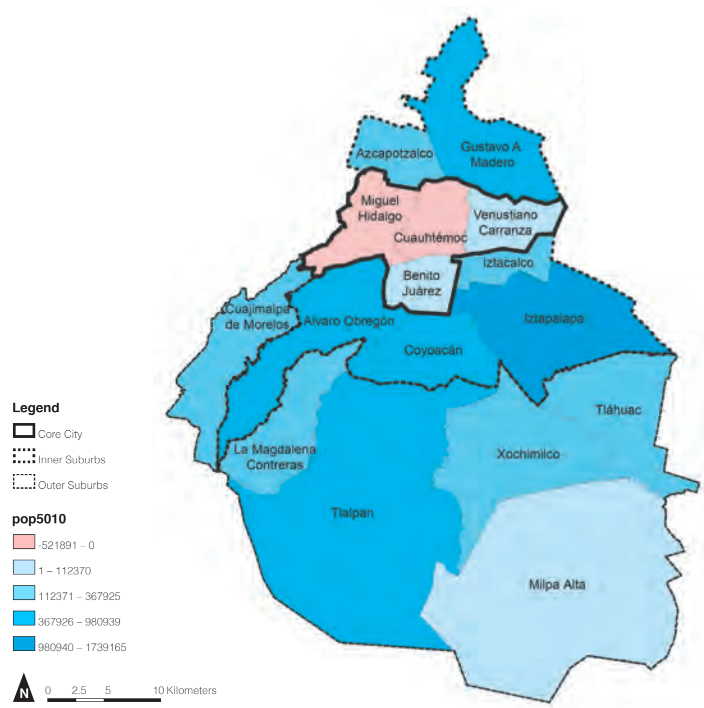
Figure 1 | Population distribution within the Federal District



Delegaciones

The population distribution within the Federal District has shifted away from the core, with outlying areas gaining population and associated development at the expense of the city center (Figure 1). The four central districts that constitute the traditional definition of Mexico City (Benito Juárez, Cuauhtémoc, Miguel Hidalgo and V. Carranza), collectively sustained a population loss of 1.2 million from 1970 until 2000. The steepest decline occurred in the 1980s, partly as a result of the 1985 earthquake, which caused heavy damage in the central part of the city. Other contributing factors have been declining birthrates and migration to primarily the inner- and outer-city (Table 2). The six 'inner' delegaciones continued to grow until 1980, when the aggregate population leveled off at just over 5 million.[3] Over the past two decades, the inner-city boroughs saw their population grow by less than four percent; these same areas grew by over 400 percent between 1950 and 1970.[4] The peripheral areas in the southern part of the District have consistently gained residents, but the rate of growth has declined considerably. The outer areas nevertheless surpassed the population of the core in 2010 (Figure 2A & 2B).

Figure 2A | Population change in Mexico City, 1950-2010



3 This result is heavily influenced by the continued growth in Iztapalapa, where the population rose from 1,262,000 in 1980 to 1,816,000 in 2010. The aggregate population of the remaining inner delagaciones fell from 3.92 million to 3.33 in 2010.

4 Schteingart (2001) includes several municipios in the State of Mexico in her definition of inner ring boroughs.

Figure 2B | Percentage of population change in Mexico City, 1990-2010

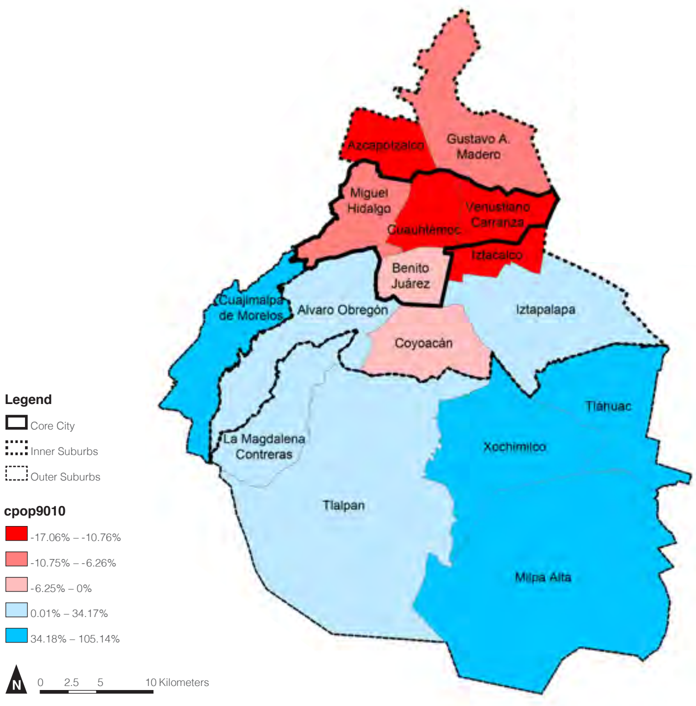


Figure 3A | Percentage change of household in Cuauhtémoc, 1990-2000

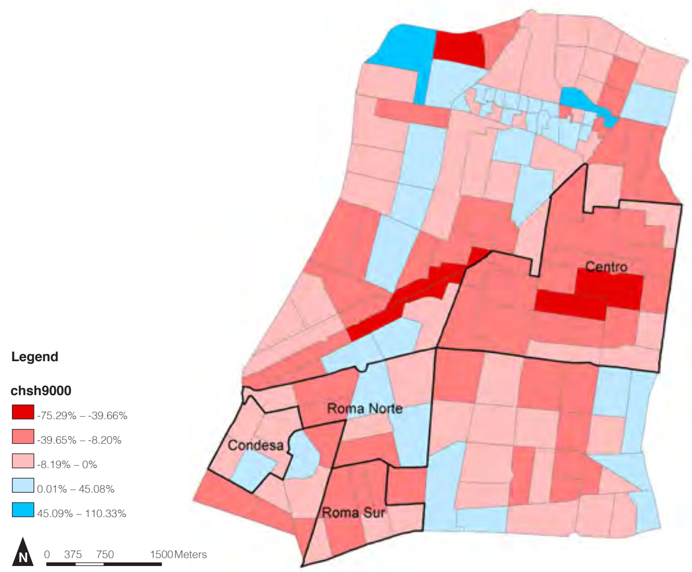
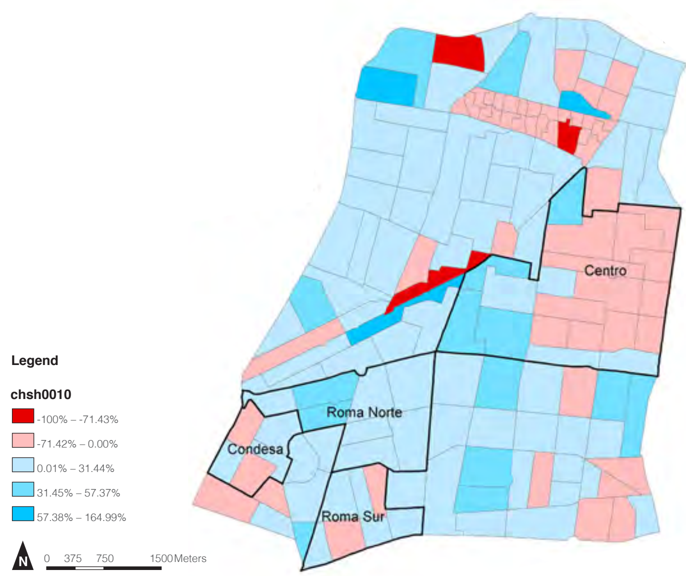


Figure 3B | Percentage change of household in Cuauhtémoc, 2000-2010



Communities and neighborhoods

Although available data are more limited, it is also possible to consider population dynamics at the neighborhood level during the past two decades. The Cuauhtémoc delegación, as a whole, lost population steadily between 1950 and 2000, as population declined by more than half. Between 1990 and 2000, Cuauhtémoc had the largest absolute and relative population loss among the core area delegaciones (Figure 3A & 3B). Yet, during this same period, ten percent of the neighborhoods in Cuauhtémoc actually gained in population. During the first decade of the current century, the aggregate population of Cuauhtémoc rose by about three percent. The number of neighborhoods recording increases, rose to 96, almost 62

Table 2 | Federal District population redistribution, 1960-2010

	Population				Change		
	1950	1970	1990	2010	1950-1970	1970-1990	1990-2010
Total	3,050,441	6,874,165	8,235,744	8,851,080	125.3%	19.8%	7.5%
Core	2,234,795	2,902,969	1,930,267	1,721,137	21.9%	**-33.5%**	**-10.8%**
Inner City	666,444	3,516,242	4,964,396	5,148,045	427.6%	41.2%	3.7%
Outer City	149,203	454,954	1,341,081	1,981,898	204.9%	194.8%	47.8%

Source: Instituto Nacional de Estadística y Geografía (INEGI)

Table 3 | Population change in the Mexico City core

	Population			Change	
	1990	2000	2010	1990-2000	2000-2010
Benito Juárez	407,811	360,478	385,439	**-11.6%**	6.9%
Cuauhtémoc	595,960	516,255	531,831	**-13.4%**	3.0%
Miguel Hidalgo	406,868	352,640	372,889	**-13.3%**	5.7%
V. Carranza	519,628	462,806	430,978	**-10.9%**	**-6.9%**
Total	1,930,267	1,692,179	1,721,137	**-12.3%**	1.7%

Source: Instituto Nacional de Estadística y Geografía (INEGI)

percent of the total. The geographic patterns of population gains and losses at the colonia and neighborhood levels are not as orderly as at the delegación level, however (Table 3).

The population numbers represent only part of the story, however. The total number of households in Cuauhtémoc and the other core area delegaciones has been increasing more rapidly than the population since 2000. Household size increased in only four neighborhoods. As the average household size fell from 3.28 in 1990 to 2.90 in 2010; the number of households rose by some 18,000 (15 percent).

The variation within Cuauhtémoc is illustrated by four colonia (communities) in the southwest quadrant of the delegación. Each of the four (Condesa, Historicio Centro, Roma Norte and Roma Sur) declined in population between 1990 and 2000 (Table 4). Every neighborhood within these communities recorded a drop in population during the 1990s. In the next decade, however, Roma Norte's total population increased, while the rate of loss leveled off in the other three colonia. Almost ten percent of the census tracts (primarily in Roma Norte and Centro Historico) have gained population since the turn of the century.

Table 4 | Colonia profiles

	Condesa	Historico Centro	Roma Norte	Roma Sur
Population 1990	15,916	90,065	27,873	23,105
Population 2000	13,159	70,973	23,989	18,893
Population 2010	11,797	87,443	25,240	18,226
Households 1990	4,686	22,649	8,119	6,938
Households 2000	4,623	18,765	7,791	6,359
Households 2010	4,508	19,663	9,362	6,751
Persons/household 2000	2.82	3.64	2.99	2.94
Persons/household 2010	2.38	3.28	2.53	2.56
Lived elsewhere five years earlier 2010	6.4%	4.7%	7.8%	6.4%
In labor force 2010	70.1%	67.6%	68.6%	66.1%
Average school years completed 2010	14.0	10.1	13.25	13.40
High income 2000	43.1%	10.7%	33.4%	37.5%
With own vehicle 2010	62.5%	19.5%	50.9%	52.8%
Owner occupied 2000	51.9%	43.9%	39.9%	48.3%
Vacancy rate 2010	11.2%	14.2%	12.8%	11.4%

Figure 4A | Percentage of high income population in Cuauhtémoc, 2000

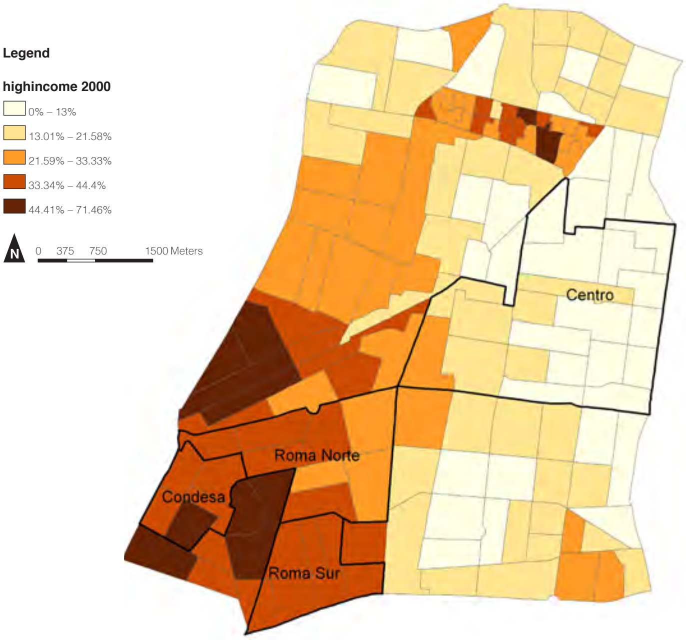
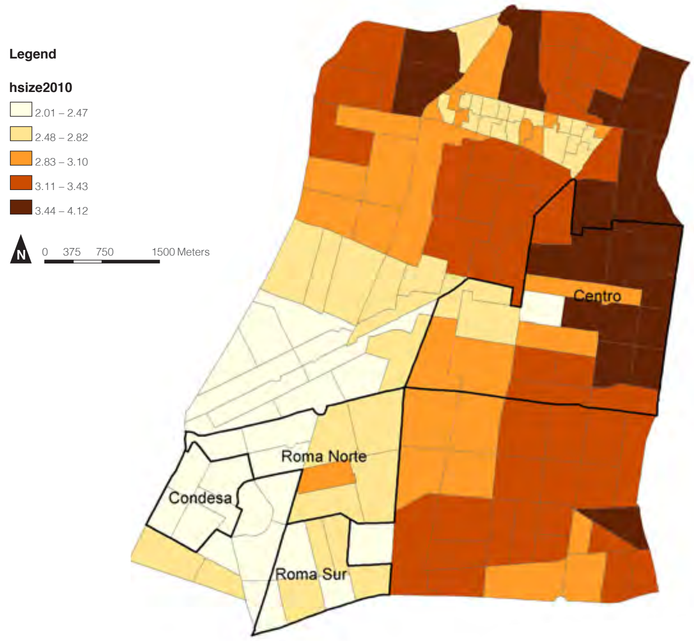


Figure 4B | Household size in Cuauhtémoc, 2010



In the most recent decade, the number of households increased in Rome Norte and Historico Centro. A sharp decline in average household size, however, has led to an overall population decline (Figure 4A & 4B). Three of the colonia now have a population per household of about 2.5, compared to an average of close to three in 2000. The Historico Centro had the smallest average decline, entering 2012 with an average household size of 3.28. In 2010, this was the only colonia in which there were any neighborhoods where the average household size is larger than three persons. The neighborhoods in Condesa and Roma not only have the smallest households but they also have the largest concentrations of higher income wage earners.

Other changes are occurring in these colonia, including burgeoning arts and entertainment scenes in Condesa and Roma Sur, along with such 21st century necessities as Starbucks and bicycle rentals. These areas, heavily damaged in the 1985 earthquake, have some opportunity to develop more modern housing. These areas include a mix of single family homes and apartments. These indicators of gentrification do not extend to the Historico Centro, where more traditional commercial areas remain (Figures 5 and 6). Parts of this latter area were also damaged by the earthquake, and the pace of redevelopment has been slow until recently. In particular, new high rise residential buildings along the Paseo de Reforma corridor have the potential for changing portions of this colonia as well (Figure 7).

Figure 5 | Retail and commercial areas

Historico Centro

Condesa

Figure 6 | Housing areas

Roma Sur

Condesa

The demographic changes since 2000, along with environmental and infrastructure improvements, suggest a more positive future for Mexico City. While many significant problems remain, there is now reason to believe that the city can be managed and that its total collapse is not imminent.

A key to further improvement is a better understanding of the interactions between these population dynamics and the built and natural environments. Some of the questions that will have to be addressed include:

While the Mexico City Metropolitan Area continues to grow and to experience a host of problems, the vision for its future is much less pessimistic than it was 30 years ago.

- What is attracting the increasing population of some neighborhoods in the city center (and not others)? What are the characteristics of those moving to the city center? Is this an example of gentrification, with higher income households occupying former low income neighborhoods? Or are lower income households occupying space that has been abandoned by middle class households moving to peripheral neighborhoods?
- What role do existing environmental conditions play in these changes? Have improvements in air quality contributed to making living in the city center more attractive? Does traffic congestion (despite continued innovation) encourage core area locations? What effects have corporate relocations, moving back to the core from outlying areas such as Santa Fe, had on attracting new city center residents?
- There are additional questions of public policy. Should the current trend of re-densification of the core be encouraged and supported? How should public policy address the conflicts between new developments and heritage preservation? What new development controls (architectural review, density regulations, parking standards, etc.) will be required? Should efforts to encourage affordable housing development in the core and inner delegaciones be continued as is, restructured or abandoned? How should public policy balance investments in developments at the periphery and in the core?

Urban policy and planning throughout Mexico has had significant limitations, not in the quality of analysis and the development of regulations, but more often in the implementation of policies. For example, the Federal District has highly sophisticated air pollution monitoring systems but they lack the ability to address violations emanating from across the

Figure 7 | Historico Centro

Present

Future

border in the State of Mexico. While there is a recognized need to expand both highway capacity and the public transportation system, limited funding contributes to a growing backlog of projects. Whether because of lack of capacity or corruption, zoning and other development controls are frequently ignored with impunity. Partisan politics may play a role in limiting support from the Federal government for city projects. Mexico City remains a city with serious problems not only in terms of environment and quality of life concerns, but also in areas such as economic inequality, adequate income and municipal finances. The effects of global climate change (including an expected increase in average temperature – leading to more hot days and heatwaves, more flashfloods and increased drought periods in the summer months, to name a few) add another layer of complexity, further exacerbating the city's socio-environmental problems (Ibarrarán, 2011).

There are no 'one size fits all', 'silver bullet' solutions to urban problems. Historical and cultural differences make efforts at global urban policy transfer particularly difficult (Mexico City is not Memphis, or even Mumbai). But there are useful parallels that can be examined. Even though the comparative global approach is unlikely to yield universal solutions, it may help policy makers in other large cities to avoid costly mistakes. This population redistribution within the boundaries of the Federal District resembles patterns that are familiar in many older American metropolitan areas, such as Detroit, Cleveland and St. Louis. Nevertheless, Mexico City may provide useful examples of how other large metropolitan areas can begin to effectively address similar problems. As this research progresses, we hope to identify some of these relevant strategies.

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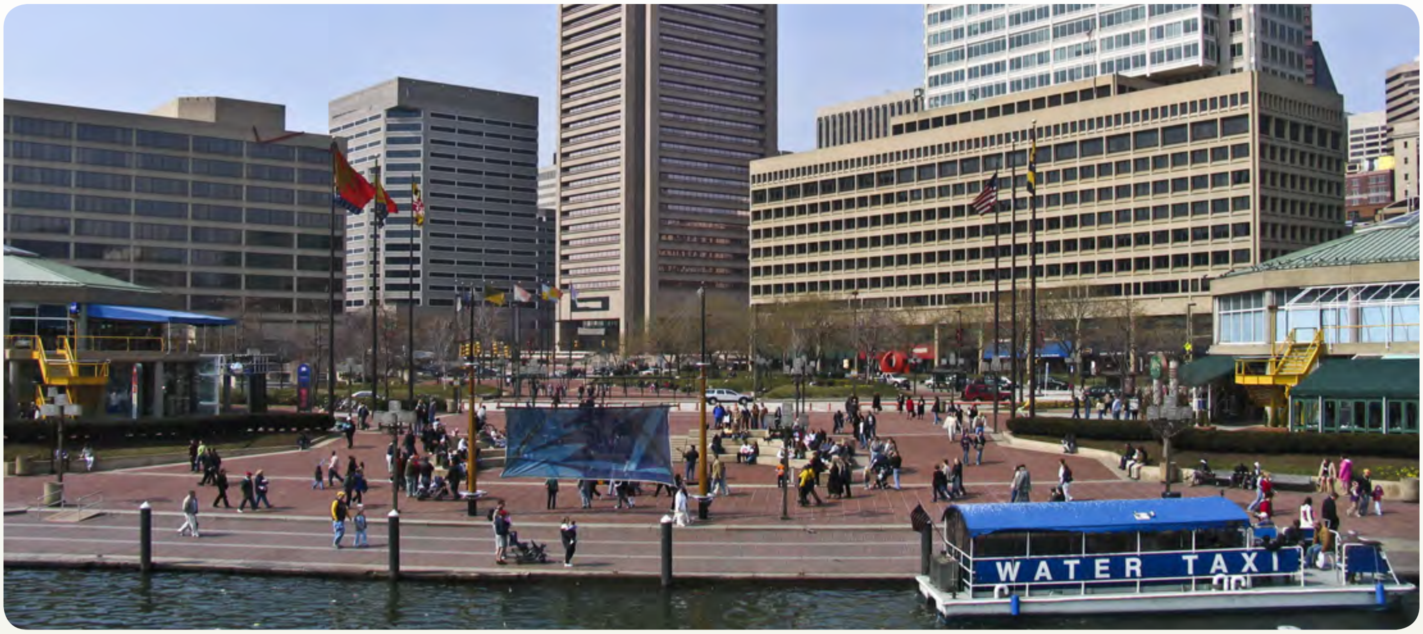


Baltimore, Maryland, USA

Developing Spatial Economic Models of Land Change for Policy Simulation

Elena G. Irwin and Douglas Wrenn

Human uses of land produce large social benefits in the form of food, fiber, shelter and other essential goods and services, but also generate a range of environmental impacts including carbon emissions, soil and water degradation, alterations of habitat and hydrologic cycles, and loss of biodiversity (Kalnay & Cai, 2003; Postel et al., 1996; Sala et al., 2000; Tilman et al., 2001; Vitousek et al., 1997). The scale of land use impacts has increased dramatically over time with global population and development. Many scientists believe that current global land use practices are undermining the Earth's long-term ability to sustain food production, freshwater and forest resources, and other provisioning ecosystem services on which humans depend (Foley et al., 2005; Pielke Sr., 2005; Reid et al., 2010). While these concerns are global, land use occurs in local settings in response to local, regional and global factors. Thus achieving more sustainable land use practices relies on policies that can effectively manage land use and land change processes at local and multiple scales. Because the impacts vary across space, an understanding of the spatial pattern of land use and land change at local scales is also important.

Land change modeling is an important tool for analyzing the effects of policy on land use outcomes and for predicting the changes in land use patterns under baseline and alternative future scenarios (Rounsevell et al., 2012; Turner et al., 2007). Generating landscape predictions requires an understanding of human behavior and, in market-based economies, some representation of land markets. Drawing on economic and geographic theories of land use and location, researchers have developed spatially disaggregate economic models of land change and usefully applied them to conducting policy analysis of land markets. Here, we provide an overview of the basic structure of these economic models of land use change and then illustrate two examples from our own work with the Baltimore Ecosystem Study (BES) urban Long-term Ecological Research (LTER) site.

An overview of spatially disaggregate economic models of land use

Economic models of land change begin with a model of the underlying microeconomic behavior (e.g., utility or profit maximization) that determines demand and supply relationships. Fundamental to models of land markets is the price mechanism, which determines individual choices and, in turn, is determined by the cumulative choices of individuals within a given market area. Price is a quintessential emergent property of any market - it arises at an aggregate scale from the autonomous actions and interactions of individuals and in turn constrains individual choices. Accounting for this two-way feedback between individual choices and market price is a central modeling challenge in economics. This challenge is further complicated in spatial models of land change since the dependence is not only on the cumulative outcome of individual choices and market prices, but on the spatial distribution of both individual choices and prices.

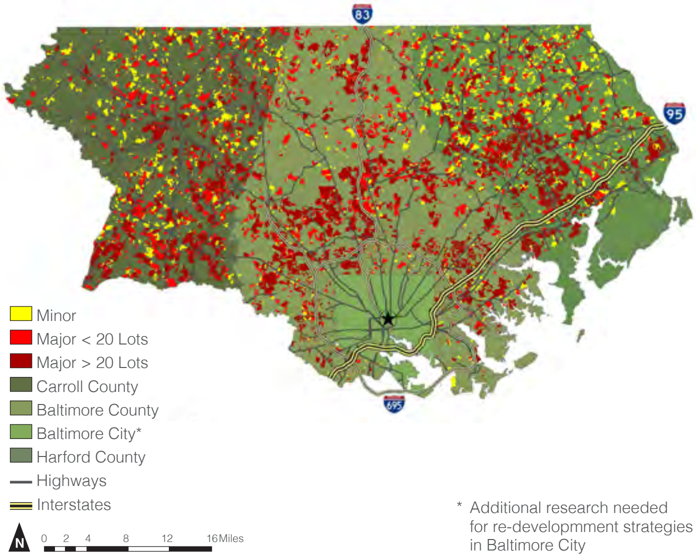
> Our central research goal to-date has been to develop process-based models of urbanization to better understand the link between local land management policies, patterns of urban development and impacts on water quality and other urban ecosystem services.

The concept of a price equilibrium is used to ensure that individual choices and aggregate outcomes are consistent with each other. Although equilibrium can be defined in various ways, the condition of market clearing - meaning that prices adjust such that markets clear (i.e., excess demand and excess supply are zero in all factor and output markets) - is standard. Equilibrium may be static, in which agents are myopic and prices and land use patterns are unchanging, or dynamic, in which agents are typically forward-looking and prices and land uses are changing over time subject to a constant market clearing condition. A common misperception is that economic equilibrium necessarily implies a static condition, which is not the case. For example, in a dynamic model of landowners, the forward-looking expectations of landowners over future costs and returns influence their land use decision today. Economic models of land use and land change differ in how equilibrium in the relevant input and output markets is defined. In local land and housing markets, prices are distinguished by space and depend not only on the quantity of land in alternative uses, but also on the spatial distribution of land uses.

A central challenge is to develop spatial dynamic land change models that account for market conditions and that can be linked with ecosystem models to generate predictions of policy impacts on land use and ecosystem services. Two main approaches to modeling land use change are used in economics: (i) structural models, which explicitly represent both the underlying microeconomic behavioral process, e.g., profit maximization or cost minimization, and the price mechanism and (ii) reduced-form models, which express land use or land change as a function of spatial variables that influence prices, e.g., soils, slope and distance to urban areas, but that omit prices themselves from the model. The advantage of a structural approach is that the underlying demand and supply processes are explicitly represented. However, traditional structural models are highly stylized and aggregate and thus cannot accommodate the necessary spatial heterogeneity and dynamics. On the other hand, reduced-form models are typically estimated using micro-level spatial data on parcels or pixels, but lack the structural representation to model dynamics over time. New approaches, including econometric estimation and simulation of equilibrium-based structural models and simulation of agent-based models, are providing useful approaches that have begun to bridge the gap by combining spatially-detailed parameter estimates with simulation of a structural model of land use changes.[1]

1 More detailed reviews of these and other spatially disaggregate land use models can be found in Brady & Irwin, 2011; Irwin, 2010; Irwin et al., 2009; and the chapters by Irwin & Wrenn, Klaiber & Kuminoff, Parker, and Plantinga & Lewis in *The Oxford handbook of land economics* (Duke & Wu, Forthcoming).

Figure 1 | Carroll, Baltimore, and Harford County Subdivisions 1960-2007



Examples from the Baltimore Ecosystem Study

Like many metropolitan regions of the U.S., the Baltimore, Maryland region contains substantial variations in land use patterns across urban, suburban and exurban areas. Our central research goal to-date has been to develop process-based models of urbanization to better understand the link between local land management policies, patterns of urban development and impacts on water quality and other urban ecosystem services. Figure 1 illustrates these patterns in three Baltimore metropolitan counties that contain a range of development from high-density suburban to low-density exurban development to agricultural and rural land. To study the evolution of these patterns over time, we reconstructed the residential subdivision history for these three counties (Baltimore, Carroll and Harford counties) using historical subdivision plat files and county tax assessors GIS databases. We have used these data to construct a new measure of leapfrog development based on the road network and the timing and location of subdivision development (Zhang et al., 2012). Applying this to quantifying subdivision development patterns from 1960-2005 in Carroll County, we find that leapfrog development is much more persistent than would be expected based on standard urban economic models – as of 2005, over 30% of developable land that had been skipped over in favor of land that was farther away still remained undeveloped. This presents a puzzle: what factors can explain scattered urban development patterns?

Wrenn (2012) uses the historical subdivision data from Carroll County with data on the timing of individual subdivision plan approvals by the local county planning authority to investigate the influence of uncertain regulation on development timing, intensity and patterns. The most substantial difference in subdivision approval times is between major subdivisions, which are four lots or greater and typically located in higher-density suburban areas, and minor subdivisions, which are 2-3 lots and primarily located in the agriculturally zoned areas of the county. He hypothesizes that "time is money" and that the substantial difference in the implicit regulatory costs arising from the approval time necessary for a major versus minor subdivision causes developers to substitute away from major subdivisions and build more minor developments. He tests this hypothesis by constructing a dynamic variable that predicts an ex-ante expected approval time for each undeveloped parcel and for each time period of the model, 1995-2007, and estimating a sample selection model of land development in which the landowner chooses the optimal density of development conditional on the discrete choice to subdivide the parcel. This hypothesis is confirmed by the econometric model results. Spatial simulation is used with the estimated parameters to generate predicted landscape patterns under a baseline and alternative policy scenarios that investigate the effect of reducing the approval times of major subdivisions. The findings reveal that this doesn't change the total amount of development, but does substantially alter the spatial pattern of the development by increasing the amount of larger subdivision development located closer to existing urban areas. The results provide a new explanation for scattered urban development and show how policies that unintentionally have fostered this type of pattern can be modified to reduce their unintended impacts. In addition and similar to Lewis et al. (2009), the model accounts for both the discrete land use change of the parcel and the continuous nature of the density of development that occurs on the parcel.

In other work that seeks to explain urban patterns of leapfrog development, Chen et al. (2012) develop an agent-based model of exurban land markets and land change that accounts for key sources of spatial and agent heterogeneity. They begin with a model of utility maximization with households that are heterogeneous in income and a stylized two-dimensional landscape that is distinguished by distance from the urban center. An auction model is used to derive the household's optimal bid for land that accounts for preferences, income and basic market conditions, including market conditions arising from the number of competing bidders and relative land supply for each location. Market conditions vary systematically over space and time, which generates differences in bids and variations in household utility across space and over time. This permits the simulation model to "step through time" by providing a temporal and spatial ordering of the location choices of households based on their utility-maximizing location decisions. Chen et al. hypothesize that leapfrog development can emerge if households are able to retain a larger surplus at more remote locations, which is confirmed by the main results of the paper. While the approach by Chen et al. is similar in some ways to other simulation-based urban economic models (e.g., Caruso et al., 2007; Newburn & Berck, 2011), it differs in that the static spatial equilibrium assumption is relaxed. The approach is similar in some ways to other agent-based models that incorporate market conditions and price formation (Filatova et al., 2009a; 2009b; Magliocca et al., 2012), but improves on the specification of the bidding model by deriving bids from a structural model of utility maximization. Like other agent-based models, the modeling framework is flexible and agent and spatial heterogeneity can readily be incorporated into the model. By introducing greater economic structure into the agent-based modeling framework, this model narrows the gap between urban economic models of a static spatial equilibrium and heterogeneous, dynamic agent-based models of land change. Bridging this gap is critical for developing spatial dynamic land change models that account for market conditions and that can be linked with ecosystem models to generate predictions of policy impacts on land use and ecosystem services and to assess sustainability.

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