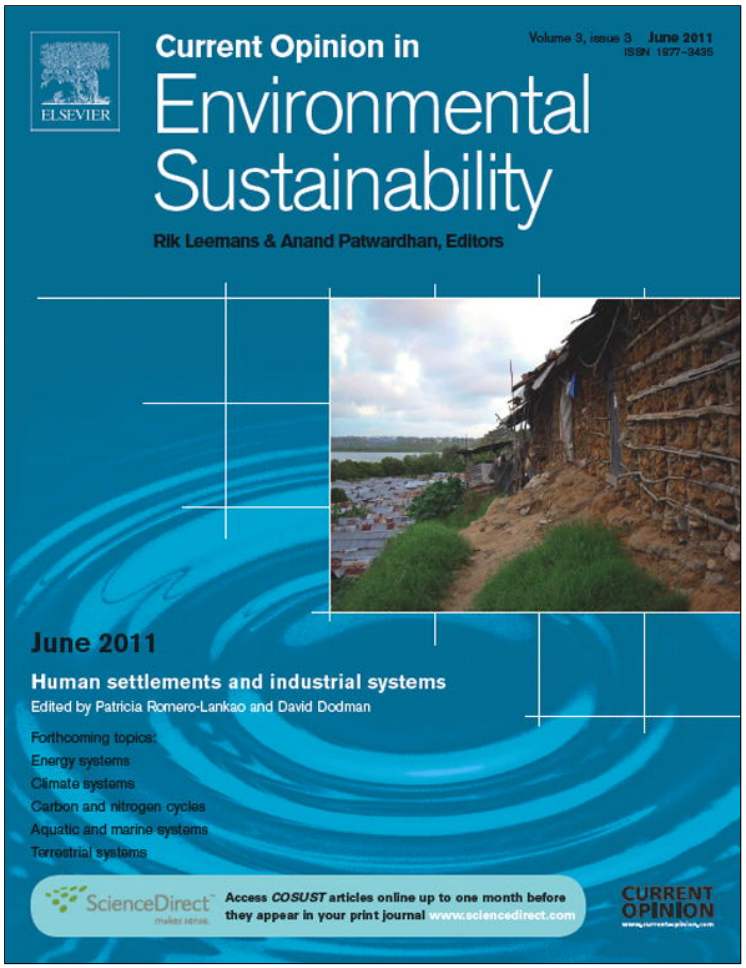

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Climate change and urban resilience

Robin Leichenko

The notion of resilience is gaining increasing prominence across a diverse set of literatures on cities and climate change. Although there is some disagreement among these different literatures about how to define and measure resilience, there is broad consensus that: (1) cities must become resilient to a wider range of shocks and stresses in order to be prepared for climate change; and (2) efforts to foster climate change resilience must be bundled with efforts to promote urban development and sustainability. Emerging issues for future study highlight some of the challenges associated with practical application of resilience approaches. These include responding to equity concerns associated with uneven patterns of resilience both within and across cities, assessing the costs of implementing resilience strategies, and identifying options for harnessing the innovation potential in cities as a means to foster resilience and sustainability.

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Introduction

The notion of resilience is gaining increasing prominence within the literature on cities and climate change. Frequently used terms such as 'climate resilient,' 'climate-proofing,' and the 'resilient city' emphasize the idea that cities, urban systems, and urban constituencies need to be able to quickly bounce back from climate-related shocks and stresses [1,2••,3,4]. Enhancement of resilience is widely cited as a key goal for both adaptation and mitigation efforts in cities and urban regions [5–8]. There is also a growing set of studies that rigorously explore how resilience is connected to other key concepts that appear within the climate change literature including vulnerability, sustainability, adaptation, and transition [2••,9–16]. In examining recent literature on urban resilience, this review recognizes the growing ubiquity of the term 'resilience' within the literature on climate change and cities, but limits the assessment to studies that place the concept of resilience at the center of their analytical focus.

Urban resilience generally refers to the ability of a city or urban system to withstand a wide array of shocks and stresses. As such, climate change is understood as but one of the many stresses that cities face. Urban resilience studies are grounded in a diverse array of literatures, which can be broadly sorted into four categories: (1) urban ecological resilience; (2) urban hazards and disaster risk reduction; (3) resilience of urban and regional economies; and (4) promotion of resilience through urban governance and institutions. While there is much overlap and cross-fertilization among these different sets of literature, each emphasizes different facets of urban resilience and each focuses on different components of cities and urban systems. After briefly describing how urban resilience is understood and studied across these different sets of literature, the review identifies a set of crosscutting themes and emerging questions for future study of urban resilience to climate change.

Approaches to urban resilience

Across the broad array of urban resilience literatures, resilience is typically understood as the ability of a system to withstand a major shock and maintain or quickly return to normal function. Yet there is disagreement on both the characteristics that define resilience and the appropriate analytical unit for the measurement of resilience. Heterogeneity in the usage of the concept of resilience is partly rooted in the differing intellectual origins and lineages of the different research traditions [17•], but diversity of interpretation is also noteworthy within each of the subgroups described below.

The *urban ecological resilience* literature, which draws and extends upon traditional notions of ecosystems resilience [9,18,19] defines urban resilience as the ability of a city or urban system to absorb disturbance while retaining identity, structure and key processes [20]. Emphasizing uncertainties, nonlinearities, and the self-organizing abilities of ecological and coupled human–environment systems, urban ecological resilience studies have expanded from an early focus on urban-based ecosystems [21], to the analysis of urban coupled human–environment systems [22], to examination of cities and urban networks as complex adaptive systems [20]. Within this literature, extreme climate events and gradual climatic changes are regarded as shocks or stressors (fast or slow moving variables) that affect cities and urban networks [23••,24]. Recognizing the critical role that cities play as centers of

innovation, Ernstson *et al.* [23••] suggest that cities need to harness this innovation potential in ways that will build capacity to withstand shocks and to sustain ecosystem services in the face of uncertainty.

Within the *urban hazards and disaster risk reduction* literature – arguably the largest branch of urban resilience literature – emphasis is placed on enhancing the capacity of cities, infrastructure systems, and urban populations and communities to quickly and effectively recover from both natural and human-made hazards. Climate change is regarded as one of many threats, including terrorism, for which urban areas must build resilience [25,26]. Recent work in this area includes efforts to: quantify economic resilience to hazards [27]; evaluate resilience of infrastructure systems and urban built environments [28,29]; and, investigate how cities recover following disaster events, with particular emphasis on community resilience in New Orleans following Hurricane Katrina [30–32]. Other hazard resilience studies develop models of community resilience based on a wide range of quantitative indicators [33••] or measure variations in resilience of towns within specific regions based on characteristics of households [17•]. Recent studies also identify mechanisms and strategies to increase hazard resilience of poor urban communities in developing world cities [34,35].

Paralleling the growing interest in economic measurements of resilience [27] there is also an emerging body of literature on the resilience of *urban and regional economies*. This literature, rooted in economic geography and urban and regional planning, applies ideas and terminology from ecological resilience theory such as complexity, diversity, and self-organizing systems, to study the evolution of urban and regional economic and industrial systems [36,37,38•]. As with the ecological and hazard literatures, the economic resilience literature emphasizes that climate change is one of many types of shocks and stresses that urban and regional economies face [38•]. Recent studies in this vein examine the linkages between diversity, volatility and growth of urban and regional economies [39], identify factors that explain why resilience is uneven across places and locations [38], and examine linkages between resilience and long-term growth and/or decline of cities and regions [40]. The emphasis on the relationship between resilience and geographical unevenness raises important questions about the role of power and politics in influencing development paths and trajectories of different places [38•].

Studies emphasizing *governance and institutions* represent another branch of work on urban resilience. This literature focuses on questions of how different types of institutional arrangements affect the resilience of local environments [41] and how resilience thinking can influence the development of improved governance mechanisms for promoting adaptation to climate change, such as new types of social contracts [42•] and community-based adaptation efforts [43]. Governance studies have also considered how resilience principles such as adaptive management can be used to promote sustainability in highly developed coastal zones [44,45•], and which characteristics of urban governance can enhance climate resilience while at same time reducing vulnerability of urban citizens who are most at risk to climate-related shocks and stress [46••]. Some of the many characteristics of urban governance that are identified as promoting resilience include: polycentricity, transparency and accountability, flexibility, and inclusiveness [46••]. But rather than prescribing a single, 'best practice' arrangement, the governance literature advocates a diversity of approaches, suggesting that effective institutional arrangements take many different forms [41].

Crosscutting themes and emerging challenges

On the basis of the above review, several crosscutting themes emerge with respect to the issue of urban resilience to climate change:

- Climate change is one of many types of shocks and stresses that cities face, and climate change-related shocks typically occur in combination with other environmental, economic, and political stresses [1,15,23••,24,25,38•,47,48]. Promotion of urban resilience to climate change will thus require that cities become resilient to a wider range of overlapping and interacting shocks and stresses.
- Although resilience can be measured in many different ways [27,33••,38•,49], some key characteristics of resilient cities, populations, neighborhoods, and systems include: diversity, flexibility, adaptive governance, and capacity for learning and innovation [1,42•,46••,50]. These characteristics are also hallmarks of cities and urban industries that are at the forefront of technological innovation and efforts to develop sustainable urban infrastructure [23••].
- In order to contribute to long-term urban sustainability, efforts to promote urban resilience to climate change, including both adaptation and mitigation strategies, need to be bundled with broader development policies and plans [2••,3,4,44,51]. In many cases, existing policies that are aimed at addressing other urban environmental problems, such as housing in risk-prone areas, can be adapted to promote climate change resilience at little or no cost [50].

Notwithstanding general agreement that promotion of urban resilience is essential for enabling both adaptation and mitigation efforts, a number of interrelated questions and concerns are also emerging. These questions, all of which highlight the challenges associated with practical application of resilience approaches within cities, provide

important topics of inquiry for the next generation of urban resilience research:

(1) *How can issues of equity be incorporated into strategies to promote resilience?* The idea that resilience is a positive trait that contributes to sustainability is widely accepted. Yet some recent studies identify situations where promotion of resilience for some locations may come at the expense of others [38•], or enhancement of resilience at one scale, such as the level of the community may reduce resilience at another scale, such as the household or individual [52,53]. Other studies raise questions about the relationship between resilience and poverty and recommend more attention to issues of power and inequality that arise with application of resilience approaches [2••,42•]. Additional work is needed in order to identify ways that efforts to promote urban resilience to climate change can take into account the unintended consequences of these actions, both across space and at different analytical scales, in order to ensure that these efforts do not reinforce existing inequalities or create new ones.

(2) *How can cities pay for resilience? And who benefits or loses from efforts to promote resilience?* There is growing interest in understanding the costs of climate change for cities and regions, as well as the costs associated with making cities climate resilient [4]. The ability to pay for resilience varies widely across cities, as does implementation capacity. This variation is not simply a function of income but also of urban governance structures and institutions. Ayers [54] draws attention to the need for international sources of funds to build and promote resilience in low and middle income countries. Yet institutional and governance literatures suggest caution about putting programs into place from top down [42•]. In order to ensure that external financial incentives that are intended to promote resilience do not undermine self-sufficiency of local communities. There is also a need for further attention to the distributional consequences of actions intended to promote urban resilience, including identification of social groups, industries, and urban neighborhoods that will benefit from or bear the cost of resilience efforts.

(3) *How can the innovation potential of cities be harnessed to promote resilience?* Cities are sites of social, political, economic and technical innovation. This innovation potential can be drawn upon to develop and implement strategies that promote resilience of urban ecosystems and coupled human–environment systems, but new forms of governance are needed to foster these efforts [23••,40]. New approaches to urban governance are also regarded as critical for efforts to bundle resilience with broader development efforts [51]. How to promote these approaches, particularly in light of entrenched political power in many cities [38•], is an important question for further work.

Conclusion

Diversity is a key tenet of resilience theory, and the diversity of approaches to urban resilience identified above is a testament to the flexibility and adaptability of this burgeoning research area. Yet because the concept of resilience concept is quite plastic — similar to the plasticity of climate change identified by Hulme [55] — resilience is sometimes loosely equated with reducing vulnerability or enhancing adaptive capacity. In order to ensure that the term 'resilience' retains its utility, there is a need for continued questioning of how the concept is used and applied to urban areas. As resilience becomes mainstreamed into efforts to climatize development [2••,4] there will also be a need for vigilance on the part of researchers, policymakers, and private actors to ensure that enhancement of resilience to climate change continues to foster positive social change [56] while also contributing to long-term sustainability.

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