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Research Paper

Advancing urban sustainability theory and action: Challenges and opportunities

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HIGHLIGHTS

- We present a conceptual framework for urban transitions of various kinds.
- We use the concept of inertia to address various theoretical frameworks.
- Inertia in urban ecosystems includes institutional, infrastructural, and social components.
- We explore sustainable solutions that both "tweak" and transform urban inertias.
- We introduce a novel research network to facilitate and inform urban sustainability.

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ABSTRACT

Urban ecology and its theories are increasingly poised to contribute to urban sustainability, through both basic understanding and action. We present a conceptual framework that expands the Industrial → Sanitary → Sustainable City transition to include non-sanitary cities, "new cities", and various permutations of transition options for cities encountering exogenous and endogenous "triggers of change". When investigating and modeling these urban transitions, we should consider: (1) the triggers that have induced change; (2) situations where crisis triggers change; (3) why cities transition toward more sustainable states on their own, in the absence of crisis; (4) what we can learn from new city transitions, and non-sanitary city transitions; and (5) how resource interactions affect urban transition s.

Several existing theoretical frameworks, including sustainability, resilience, adaptation, and vulnerability, may be helpful when considering urban transitions. We suggest that all of these theories interact through inertia in urban systems, and that this multi-faceted inertia—e.g. institutional inertia, infrastructural inertia, and social inertia—imparts degrees of rigidity that make urban systems less flexible and nimble when facing transitional triggers and change. Given this, solutions to urban sustainability challenges may be categorized as those: (1) that "tweak" the current systems and work with or even take advantage of the inertia in those systems, versus; (2) that are more "transformative", that confront systemic inertia, and that may require new systems. We propose that a model for addressing urban sustainability in the context of relevant theory, and for bridging research and practice, should focus on intercity comparisons. And one mechanism to facilitate this approach is a newly formed interdisciplinary Research Coordination Network (RCN) that focuses on urban sustainability by integrating urban research while incubating solutions-oriented products and collaborative partnerships with practitioners. The Network includes more than two dozen cities in five continents that are in various degrees of transition. In the true vein of sustainability science, our Network activities are incubating societally-relevant

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solutions through projects that will lead to tangible, "on the ground" sustainable solutions for all types of cities. Our ultimate goal is to understand the process by which cities become more sustainable while affecting that process through action inspired by knowledge.

1. Introduction

There are many ways to define "sustainability", but most interpretations of this concept involve a focus on human needs and values, and an emphasis on the future (e.g. Brundtland Report, 1987). The pressing needs to promote sustainability have stimulated a new and maturing field of science—sustainability science—that focuses on solving problems and meeting challenges, rather than on traditional disciplines (Spangenberg, 2011). This new field of inquiry seeks to address symbioses between human activity and the environment (Rapport, 2007). One specific challenge facing sustainability science is the global increase in urbanization. New and expanding cities present both challenges to and opportunities for sustainability (Weinstein, 2010). Cities worldwide are facing many challenges, including exploding population, inadequate or failing infrastructure, as well as economic and environmental disruptions. Thus, understanding urban sustainability and improving the ability of policy-makers to achieve sustainable management are pressing needs of the 21st century (Birch & Wachter, 2008; Naess, 2001; Register, 2006).

Urban ecology as a discipline is increasingly poised to contribute to urban sustainability. In the last 20 years, the discipline of urban ecology has grown from a relatively traditional examination of ecology *in* cities (Collins, Kinzig, & Grimm, 2000) to investigations of the ecology *of* cities (Grimm, Grove, Pickett, & Redman, 2000; Pickett et al., 1997b). In the former approach, research focuses on traditional ecological structures and functions, but in an urban setting. Studying the ecology *of* cities is generally a more holistic approach where the city itself is the ecosystem under scrutiny and *Homo sapiens* is acknowledged to not only be part of the system, but in fact the system's dominant species. Conceptual approaches that guide urban systems research are now typically interdisciplinary and include both biophysical and social–cultural components that interact through the purveyance of ecosystem services and through the press-pulse forces of management and disturbance (Collins et al., 2011; Grimm et al., 2012). This interdisciplinary nature of contemporary urban ecology, along with its concern with the ecological processes underlying ecosystem services, allies it well with sustainability science.

The science behind sustainability is an inherently interdisciplinary endeavor that ultimately seeks solutions to social–ecological problems. That said, because human and biophysical dynamics are inextricably coupled in urban systems, urban sustainability provides opportunities for more transdisciplinary conceptual approaches that do not differentiate between ecological and human-derived structures or between ecological and human-mediated functions (Pickett & Grove, 2009). In bridging from interdisciplinary to transdisciplinary approaches, our definition of the latter is similar to that of Ahern, Cilliers, and Niemelä (2014), where the focus includes the social, institutional, designed, built, and biophysical components of urban ecosystems and where urban systems research includes not just an array of biophysical, design, engineering, and social expertise but also includes real world city practitioners. To that end, urban sustainability moves us toward an ecology *for* cities, where the "knowledge to action" model invokes using what we have learned about urban ecosystems to actively make cities better and more sustainable places to live.

As an example of how the interdisciplinary entanglements in studying urban ecosystems may be made more transdisciplinary, we use the water system, or hydro-ecosystem, of an aridland city (e.g. Phoenix, AZ, USA). In the well-accepted interdisciplinary conceptualization of this urban water system, per Grimm et al. (2012), the structural and functional aspects of the biophysical and social–cultural components are connected, yet remain separated. The purveyance of ecosystem services is a key connection between these two domains, but this conceptualization does not easily incorporate the services provided by the human-derived elements of urban ecosystems. Our more transdisciplinary conceptualization more fully integrates the human with the biophysical by not separating human and ecological structures (e.g. infrastructure, land use/land cover, vegetation, soils, and water bodies) or functions (e.g. water use decisions, water management, evapotranspiration, plant production, and biogeochemical cycling; Fig. 1). In this example, water enters the city as municipal water supply and as precipitation and, because this example city is located in an arid climate, the former sources dominate the inputs (note the larger input arrow in Fig. 1). The geomorphological template of the landscape dictates major distribution pathways of water across the city, but human decisions about the management of water, including storm water and water supply, are critical components of this urban hydro-ecosystem structure. Biophysical processes such as evapotranspiration, plant production, biogeochemical processing, and groundwater recharge are important processes in this hydro-ecosystem, but human decisions about water use, landscaping, irrigation, and water management tend to dominate hydro-ecosystem function.

In this example, we separate the water system into horizontal and vertical components of urban water flux (Fig. 1). Horizontal components are dominated by water purveyance and stormwater runoff, both of which follow the geomorphological and topographic template of the landscape but are strongly regulated by human design and management decisions. Vertical components include evaporation, transpiration by vegetation, and groundwater recharge; these are a function of both ecological processes and human decisions about the magnitude and distribution of those processes. For example, landowners and managers decide on where to locate [i.e. where to plant] vegetation, how much irrigation to apply to that vegetation, and where to locate open water amenities. The design of stormwater infrastructure will also dictate where rainwater infiltrates vertically into the groundwater of the city (Fig. 1). The challenge with this type of transdisciplinary approach to conceptualizing urban ecosystems is that human and biophysical aspects of structure and function must be both conceptually integrated and practically coupled. The advantage of this approach is that the importance of human decisions and actions in urban ecosystem dynamics is clear, allowing biophysical-human synergies, symbioses, and services to be more easily articulated and quantified. We argue that such synergistic approaches are crucial to understanding and planning for enhanced sustainability of urban systems.

2. From contemporary cities to sustainable cities

In the "Global North" (per Ogden et al., 2013, and others), many older cities that began as industrial cities have transitioned over the last century into sanitary cities (as defined by Grove, 2009,

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