Global urbanization as a shifting context for applying ecological science toward the sustainable city

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Abstract. There is an abundance of conceptual frameworks relevant to sustainability in urban systems. However, to advance urban ecological science and its application to sustainable urban transformations, key existing frameworks must be synthesized. This paper is a conceptual synthesis cast in essay form in order to encompass a broad range of relevant ideas. It starts from the premise that the familiar models of metropolitan and megalopolitan urban structure, of industrially driven urban development, and of the contrasts between urban and non-urban lands are manifestly inadequate representations of evolving global reality. Such inadequacy is illustrated with examples from the United States and from China. Both the form and the interactions involved in contemporary urbanization and urban change suggest the need for a new integrated framework synthesizing two existing yet still evolving concepts: (1) The urban megaregion framework accommodates the spatial extent, interdigitation of contrasting land uses, and the linked spatial relations between nominally urban and nominally rural areas. (2) The new concept of the continuum of urbanity emphasizes the shifts in livelihood and lifestyle driven by regional and global teleconnections and their joint effects on local environments and landscapes. Together these frameworks suggest a common conceptual structure for addressing urban areas of different ages, sizes, forms, and dynamics in both urbanizing and urbanized areas in developing and developed countries and regions. The synthesis of frameworks points to empirical research needs, and has the potential to better match sustainability plans and actions with the diverse urban forms and dynamics now appearing around the world.

Key words: development; globalization; megaregion; sustainable city; urban ecology; urban theory; urbanization.

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Introduction: Problem and Scope

For ecological science to facilitate urban sustainability, it is important to understand that cities, suburbs, villages, and exurbs around the world are highly dynamic and are exhibiting new forms and relations. The nature and variety of these changes go well beyond the familiar frameworks employed by ecologists, and draw attention to knowledge, data, and concepts from cities and research traditions that may be outside the experience of individual projects. We believe that combining specialized frameworks in a new synthesis is an important step to stimulate and organize new observations and analyses, and to accommodate urban changes that are not yet well documented by multi-dimensional, interdisciplinary research in urban ecological science. This paper attempts to help ecologists navigate the changing intellectual landscape represented by global urbanization.

The paper uses a narrative rather than a review or empirical format to address the extraordinary breadth of concepts and situations that can better inform urban ecological science. The argument has the following components. The focus on all forms of urbanization and their regional implications is first stated. A prevalent model of urbanization, associated with industrialization in the Global North, is examined and its failures noted. The failure of this urban development model invites consideration of the emerging model of urban megaregions, and the appreciation of the diversity of models of urbanization and urban areas that are...
appropriate across the Global East and South as well as in the dynamic urban areas of the Global North. To emphasize the functional nature of the new forms of urbanization, we employ the “continuum of urbanity,” a conceptual model that accounts for the variety and increasing scope of connections within and between urban areas, and between urban and formerly distinct rural territories. The continuum of urbanity identifies the dimensions of social, economic, and biocultural differentiation and interaction that increasingly define and motivate the form and function of complex urbanized or urbanizing regions. The new synthesis of these conceptual frameworks helps recognize the dimensions of crisis and opportunity in established, growing, shrinking, and yet to be born cities and towns. Such crisis opens the way for enhancing the sustainability of urban areas.

**Problematic Views of the City**

We use “city” and “urban” in an inclusive sense in this paper. Of course, city can narrowly refer to the central business district, or to dense commercial, residential, and industrial nodes in an urban region. But the inclusive sense of urban refers to the entirety of dense, heterogeneous, extensive settlements. It refers to mosaics that include such centers, but which interdigitate with agricultural and unmanaged lands (McGrath and Shane 2012). In this inclusive sense, the terms “city” or “urban” stand for extensive urbanized areas. Beyond this definition, there are shortcomings of specific models of the urban and of urbanization.

The concept of “city” has accumulated many assumptions. This does not mean that everybody makes all of these assumptions, but they clarify the conceptual space. For roughly the past 100 years, the city has been thought of in these ways: (1) centralized, (2) discrete, (3) industrially focused, (4) engineered for sanitation, (5) metropolitan cores, and (6) permanent and monumental (Melosi 2000, Gandy 2003, McGrath and Shane 2012). In this inclusive sense, the terms “city” or “urban” stand for extensive urbanized areas. Beyond this definition, there are shortcomings of specific models of the urban and of urbanization.

The classic city assumptions represent a snapshot. There is also a temporal model. It takes industrial cities, regions, and countries to be the epitome of a sequence of settlement, construction, innovation, and generation of wealth. This model suggests that industrial cities are the result of a trajectory that leads to stable, complex civil, economic, and material conditions. “Developed” areas are materially wealthy and subsidized by resource and human inputs from elsewhere (Ford 1991). They have institutions for managing the flows of resources, the production of goods, finances, and social interactions. They are also associated with monumental architecture and grand city layout.

But this temporal model of cities is flawed. The error is summed up in the term “postindustrial.” The life of cities clearly does not end with an ideal, persistent, stable industrial condition (Decker et al. 2002). Although cities have life, they do not have an organism-like life cycle (Light 2009). In many situations that had been touted as the height of city development in the mid-20th century, further change occurred. Many former industrial powerhouse cities lost much of their industrial economic base and jobs, along with huge proportions of their populations.

**An Evolving Regional Urban Reality**

Another aspect that ecological urban theory must accommodate is the mutation of the metropolis into something larger, less dense, and more regionally diffuse than the industrial model suggested (Regional Plan Association 2007, McGrath and Shane 2012). The industrially powered, centralized “mother city” was the focal settlement of an extensive region, including subsidiary settlements. In some cases, the focus extended to a subcontinental region, an entire nation, or a global empire, which drew resources and labor from a broad catchment into the metropolis (Cronon 1991). A final feature to include is density. Metropolises concentrated workers within easy distance of jobs, and many mother cities that reached their zenith during the early- to mid-20th century comprised dense housing blocks, tall apartment buildings, and effective public transportation.

**Urban regions: from metropolis to megaregion**

The view of the city as metropolis has become an illusion or a memory (Soja 2000). This lapse was first codified by the term “megalopolis.” Originally coined for the changes emerging in the Northeastern United States after World War II, it referred to the string of metropolises joined by rail, engaged in coal-powered industrial production, and linked by telephone and broadcast television (Gottmann 1961, McGrath and Shane 2012). This kind of complex conurbation has continued to change, however (Dear and Flusty 1998, Lang and Dhavale 2005, Vicino et al. 2007). For instance, American and European urban areas have become less dense at their cores, and have spread into their former hinterlands. Indeed, the nodes of the megalopolis have become less distinct, and many are as well connected to the larger global context as to their neighboring cities (Sassen 2012). At the same time, new cores have been constructed, often associated with major highway intersections.

Many other changes have occurred in megalopolitan regions. For example, in the United States, megalopolis is no longer fueled primarily by industry, nor is it principally linked by rail. This altered megalopolis is termed an urban megaregion (UN Habitat 2011), representing a more regionally diffuse structure (Fig. 1).
One associated feature that has evolved rapidly is governance arrangements. Urban areas are now typically governed by a patchwork of chartered cities, villages, and towns, or counties and regional authorities, along with civil society organizations (Pincetl 2010). In the Global North, power has shifted from central cities to suburban enclaves, and the various jurisdictions can have divergent interests (Ernstson et al. 2010). In countries such as China, however, there is a strong hierarchy of governance in urban metropolitan areas, in which the center city and the surrounding satellite cities are usually within the same administrative boundary (Li et al. 2013). In such situations, megaregion governance is consolidated. In contrast, in situations where the cities, towns, and villages of an urban megaregion are under different administrative jurisdictions, governance is, in general, loosely connected through regional authorities or committees.

**Global context of regional processes**

A further important change in urban megaregions, and indeed all types of settlement, is the global reach of social, financial, and environmental actors (Sassen 2012, Seto et al. 2012). Immigration has been a driver of urban change for centuries. It continues apace, but there is a dimension of connectedness that differs now. For example, whereas immigrants to the United States in Fig. 1. Key nodes in the transformation of cities to urban megaregions. The urban models range from a “city” model, with distinct urban (U) and rural (R) areas within a single state or provincial jurisdiction; through increasing connections to nearby satellite cities and a rural hinterland in the “metropolis” model, perhaps involving two states; through the “megalopolis” model of linearly connected metropolises that span several states, but which maintain relatively distinct rural areas; and finally to the “urban megaregion” model in which connections are multiple and diffuse, with intensive interdigitation of contrasting urban and rural land cover types. Connectivity of people and materials and of communication channels are illustrated for each urban model. The media of connectivity move from relatively slow and spatially proximal in the classical city to fast and having regional and global extent for urban megaregions. In order, from city to mega region, the examples of connectivity are a horse-drawn trolley and paper mail; inter-urban electric railroad and wired telephone; interstate highway or express motorway and dial-up computer modem, and air routes and cell or satellite phones. Photo credits, all with creative commons license: trolley and postage stamp, photographers unknown; Cedar Rapids and Iowa City Interurban rail car, Jack Snell; bakelite telephone, Rob van Hilten; interstate highway, the authors; PC computer, Mark Mathosian; Dusseldorf Airport, Citizen59 (on Flickr); farmer in field with cell phone, M. DeFreese/CIMMYT.
the 19th and early 20th centuries apparently envisioned a one-way journey, there now seems to be greater integration of the new arrivals with those in “the old country.” A common phenomenon is migration aimed at remittance, and periodic or eventual return, and continued investments “back home.” This represents increased integration of urban areas into a global fabric (Seto 2005, Clemens et al. 2014).

Institutional interactions provide another global link. Of course some businesses have always maintained global connections. This is a long tradition in the United States, for example, including raw materials, finished goods, and the importation of voluntary and involuntary labor. However, investments and financial decisions now span the globe virtually instantaneously (Sassen 2012). The ready transfer of money by individuals mirrors the economic connectivity of businesses.

All this emphasizes the change in cities. We have used the Global North version of an urbanization model because that is the one most widely available to ecologists. It is also influential in countries rising in significance and integration in the global market system. However, it is becoming clearer that this model fails to describe the continuing dynamics of urban areas even in its countries of origin. We will point to processes in China both to complement the insights from the Global North, and to indicate issues that emerge from its extraordinary and unprecedented rate of urbanization.

Global Diversification of the Urban Realm

The global context calling for improvement of the urban change models introduced above is paralleled by novelty of urban patterns around the world. Urbanization now exhibits a diversification of the forms and functions of urban areas worldwide (Jabareen 2006, Kim 2007, Bossellman 2009, Cilliers et al. 2009, McGrath 2013, McHale et al. 2013). Such diversity must be reckoned with in articulating new models of urbanization. Such new models of urban change and processes may be more useful in charting sustainable urban futures than the flawed industrial/urbanization model from the Global North.

Diverse city sizes: small to huge

As urbanization spreads, the size of cities has changed dramatically. Until recently, the largest category of cities was labeled “megacities,” which denoted urban areas containing at least 10 million inhabitants (United Nations 2007). But as urban population has continued to accumulate around the world, a threshold of merely 10 million has become inadequate. The UN has added a still more populous category: the Hyper City or Meta City, hosting at least 20 million inhabitants. Leading this list is the Pearl River Delta area of China with some 49 million inhabitants. Some have suggested an additional breakpoint at 40 million, to be labeled Super Cities. It is clear that the term “city” in these cases refers to an urban region of great extent (Fig. 2).

The growth of huge urban agglomerations is not the whole story, however. Medium-sized cities, those housing from 500 000 to 1 million, are, in fact, where most urban development is projected to take place over the next few decades (United Nations Population Fund 2007). Especially in China, many of these cities will be virtual novelties on the landscape (Fig. 3).

On the one hand, this may be viewed as a positive situation because new cities are not burdened by old infrastructure or entrenched political divisions. On the other hand, in many countries, smaller cities may not have the resources necessary for effective planning or design, or for constructing truly innovative buildings and infrastructure, or for protecting green and blue spaces adequately. Paying attention to mid-sized cities and to more dispersed forms of high-intensity urban development, such as that now underway in China and in India, and likely to occur in Africa as well, could have worthwhile environmental and social benefits (Seto 2005, Bai et al. 2012, Childers et al. 2014).

Whatever the size of new or expanded urban settlements, cities are estimated to house the next 3 billion people who will likely be added to the 7.2 billion now alive.

Informal settlements and urban villages

The global changes in cities call attention to the variety of spatial city forms that exist or are emerging worldwide. One widespread form is the informal or self-built settlement (Montgomery 2008), also called slums, shantytowns, or favelas. Informal settlements are often on marginal lands—beside flood-prone streams, on steep slopes, or on uninviting and unsheltered flats. Such places are not only on physical margins, but they are also often socially marginalized. But these places are home to a large number of urban residents, and are the catchment of much urban migration (Lwasa 2013).

Urban villages are another globally relevant form. They are established rural villages that are engulfed by newer city and suburban districts (Fig. 4). In China, for example, urban villages may retain some of their rural features, including small-scale cropping or animal husbandry. Alternatively, urban villages, because they share the architectural style of the countryside, and because property holders may move to newer and more fashionable districts, can come to host large numbers of renters who sometimes retain rural ways.

Mixture and heterogeneity

There are other examples of how urban fabric differs globally. One is the fine-scale inclusion of agriculture in
cities, and not just in absorbed urban villages. In Japan, there is an effort to retain small holdings of agriculture in many of the densest urban areas. This model is being adopted in some postindustrial, shrinking cities in North America and Europe, reflecting a burgeoning interest in community gardens and urban farming.

But new global urban form also includes both high-rise districts that are the norm in some places and the low-profile, large-lot suburban or “villa” forms based on the North American, New Zealand, or Australian model. This last component, the sprawling suburb, is becoming something desired in parts of Asia, Africa, and Latin America. These forms, along with the shantytown, are combining in the urban fabric in new ways. They are arrayed in segregated mosaics, with gated communities and stark socio-economic differentiation becoming commonplace (UN Habitat 2011).

**Fig. 2.** Land cover/land use maps of Beijing from 1984 to 2010. Beijing offers an example of how the term “city” in many cases refers to an urban region of great extent. Within its administrative boundary, Beijing comprises urban, suburban, and rural areas, among which there are no clear boundaries. The developed land has been growing in places throughout the entire region, except for the mountainous areas. The portion of developed land has increased rapidly, from 8.15% in 1984, to 9.88% in 1990, to 13.33% in 2000, and to 18.08% in 2010.
Flexible habitation and movement of people

Along with the emergence of new urban forms are new ways of inhabiting the city. An important contrast with the pattern of urbanization in the Global North is the fluidity of movement between the city and distant settlements elsewhere. Permanent migration of rural populations to cities for industrial and, more recently, service and consumer employment, has been a norm since the industrial revolution. A subset of such permanent shifts in population is the general suburbanization of America, shown by the continuing conversion of periurban land to residential and commercial uses. Indeed, this urban land consumption rate is faster than overall urban population growth. Such permanent, or at least persistent, migration to urban areas is markedly different from the trends in parts of Asia and much of Africa (Myers 2011).

The difference in migration patterns is exemplified by the two-way population flux that is a conspicuous aspect of urban growth in Africa (McHale et al. 2013). People move between traditional cities, agricultural villages, and increasingly dense settlements distant from established cities. These movements are occasioned by opportunities for short-term employment, or the needs of the family. As a result, active family networks often bridge vast distances, including city and rural areas. People frequently move between the nodes of these networks, exchanging resources, labor, and financial support. Asian migrations also exhibit such ebb and flow, with temporary residence in either city or distant town. The recent replacement of the urban registration system (Hukou) in China may spur more such flexible migration. The formerly rural areas involved in these fluxes become more urban in attitude, capital, and technologies. The cities are changed as well. Crops, animals, and cooking technologies from the countryside are imported or reinforced in the city. Social networks may have more allegiance to the family at a distance than to the local neighborhood. The traditional connotations of the terms “urban” and “rural” do not fit this form of settlement and connection. Indeed, novel conceptual frameworks can help ecologists to understand the changing and diverse urban reality around the globe.

The Continuum of Urbanity: a Nascent Theoretical Perspective

Two main points have emerged so far. First, the predominant models of urbanization and of urban form reflect the experience of the Global North. These models are not universal. Even in the Global North, the urban development model no longer adequately describes urban change. Second, there are many new forms of
urban settlements evident around the world. These forms invoke different assumptions than those supporting the standard industrial urbanization model. These two shortcomings of the received view require new frameworks of urban form and process.

This section explores the "continuum of urbanity" (Seto and Reenberg 2014) as a candidate framework. This framework links with the spatial complexity summarized by the urban megaregion framework, but emphasizes the biological, social, economic, physical, and infrastructural processes that integrate the lands and systems within and between megaregions. The continuum of urbanity does not attempt to reinforce and redefine the contrast between urban and rural to fit contemporary reality, or to maintain narrow formal conceptions of the urban. Rather it summarizes evolving concepts and insights from a variety of disciplines. This conceptual continuum views spatially extensive urbanized regions as porous, multi-dimensional, differentially connected mosaics (Boone et al. 2014).

We note that the continuum of urbanity is a conceptual vehicle, and differs from the familiar policy-oriented “urban-rural integration” (e.g., Ye 2009). Although in principle, the term urban-rural integration might be defined to cover the spatially complex processes addressed by the continuum of urbanity, in practice, urban rural integration focuses on management and policy-making (Ye 2009). Urban-rural integration, among other policies, has been proposed to halt the widening of the urban-rural gap, which is largely caused by the urban-biased development strategy based on administrative separation in a dual system of urban and rural areas (Ye 2009, Qian and Wong 2012).

The continuum of urbanity as a process framework has four dimensions: (1) livelihood, (2) lifestyle, (3) teleconnections, and (4) attributes of place (Fig. 5). These dimensions represent both the physical structure of urban regions and their lived qualities (Marcotullio and Solecki 2013). Social, economic, bioecological, and infrastructural or built features are reflected in the four dimensions of the continuum. The dimensions provide a comprehensive picture of the complexity of processes in contemporary global urbanization, but do not operate as separate phenomena (Boone et al. 2014). Indeed, there are linkages among them, some direct, and some incidental. Such a continuum may play out along a literal, geographic transect, or it may be employed as an ordered abstraction that organizes thinking about the functioning of complex spatial mosaics at various scales. The sections below rely on literature summarized by (Seto et al. 2010, 2012, Pickett et al. 2013b, Boone et al. 2014, Seto and Reenberg 2014).

Fig. 4. An urban village engulfed by dense urban development in Beijing. Such villages can retain rural structure, fine-scale garden plots, and low-profile construction even when surrounded by higher density, and higher elevation city-style architecture. Social and functional differentiation may persist, or may change as farmers are replaced by migrant workers. This example is in an area converted from village to urban during the development of the 2008 Olympic precincts.
Livelihood

Livelihood deals with how people support themselves. Livelihoods encompass much of the economic context of individuals and institutions, and range from subsistence to participation in a market economy. Small-holding agriculture, for both subsistence and to raise cash, is a classic rural livelihood, but one that is becoming less viable in the face of industrial agriculture and competition from city-based land uses. Engagement in market economies is a traditional urban-based livelihood. Additional attributes of livelihood can vary along the conceptual continuum between urban and rural poles: the skill sets of individuals, the social capital of groups, the resources and materials employed in work, the networks of practice in which people engage, intellectual networks, and the daily mobility involved in achieving a livelihood. Of course, various people or groups may experience different opportunities and constraints in pursuing their livelihoods, and these may differ from an urban core to country as well.

The urban village, mentioned earlier, also exemplifies the shifting of livelihoods with urbanization in China. As rural villages, formerly devoted to farming, are engulfed in urban areas, they lose the extensive lands that had been their agricultural patrimony. Although they may receive financial compensation for that loss, their access to farming as a way of life is terminated (Qian and Wong 2012). Even more stark a separation is in those situations where residents are persuaded or coerced to sell their collectively held villages for urban development. In such cases, the village is demolished, and the residents often move to high-rise, gated developments that have exactly the same architectural and landscape architectural features as medium- to high-rise housing blocks in cities.

Lifestyle

Lifestyle has to do with social identity and behavior. It is defined by the groups with which individuals identify, their household arrangements, choices about consumption of basics and luxury goods, the symbolic behaviors adopted, and the kinds of recreational activities chosen. Lifestyle, as much as livelihood, affects environmental relationships of people based on their view of land, their sensitivities to different aspects of the environment, and the kinds and amounts or resources they use. As with livelihood, external constraints and opportunities affect lifestyle choices.

We return to displaced villagers in China as an example of urban effects on lifestyle. Village residents bought out from their previous livelihood and lifestyle, find themselves newly wealthy and installed in formal urban locations—a new city or suburb. A common result is the purchase of a luxury car, and a commitment...
to a leisurely life of conspicuous consumption. Furthermore, while the new gated apartment blocks do provide amenities for residents, shared informal common space that may have been a part of village street life or facilitated by local shopping habits, are not often provided in such new “luxury” developments, which have centralized shopping malls. These developments advertise themselves as “Tuscan style,” “desert style,” or “international style” (Fig. 6), which highlights their lifestyle implications. Many of these are so-called “ecocity” developments. While they may include admirable energy and storm-water management efficiencies, reduced dependence on local automobile use through commodious bike paths and provision of free bus service, appreciable tree-lined streetscapes, and vegetated courtyards, they seem to neglect the social features of urbanism as a way of life, and hence fall short of the ideal of promoting the social pillar of sustainability. Lifestyle points to the quality of urban areas, recognized as a key aspect of urbanism for a long time (Marcotullio and Solecki 2013).

The two dimensions of the continuum of urbanity discussed so far have pointed to the next one, connectivity. Livelihood changes and shifts in lifestyle with urbanization occur because nominally urban and nominally rural places are connected to each other, and to other urban, rural, and wild places around the world. We explore this important driving dimension of the continuum of urbanity next.

Connectivity

Connectivity is a key aspect of contemporary urbanization. Connectivity can refer to the physical infrastructure and technologies that link spatially distant places, or it can refer to the actual connecting activities. The physical connections of place include the transportation options or modes available, and the density of pathways between different locations. Transportation infrastructure, electronic media, and the actual flows across the various networks characterize physical connectivity. Connectivity can also involve information or influence. For example, cash and credit are examples of economic connectivity that are at once abstract, instantaneously mobile, limited, and differentially allocated.

Connections among people and groups may differ over various time scales. Connections extend beyond the local when migration enters the picture. Migration is a determinant of human connectivity, and whether it is directional or flexible matters.

Connectivity is also affected by the venues or media available for interaction, the options people have for communication, the existence of virtual networks, and how institutions encourage or thwart connections, either intentionally or incidentally. The fact that many connections are mediated by mobile devices, cell networks, and the Internet, increases the speed and extent of connections. But it is equally important that these technologies put connections largely under the control of individuals as compared to corporations (Terkenli 2005).

Of great significance is that many of the connections span global extent. This is referred to as teleconnection (Seto et al. 2012). Our examples of livelihood and lifestyle have pointed to some of these distant connections. Financial arrangements, cultural expectations, shifts in consumption habits, tourism, and fluxes of labor are examples of connections that may take place over distances of continental or global extent. Although long-distance connections have characterized the linked urban, industrial, and colonial enterprises for 500 years, their near instantaneous, reciprocal, and global reach now makes them crucially important to contemporary urbanization and the hybridization of the nominally urban with the nominally rural, and even with distant wild landscapes.

Features of place

The final dimension of the urbanity continuum is the attributes of specific places. Although this dimension
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includes the important idea of “sense of place” (e.g., Agnew and Duncan 1989, Beatley and Manning 1997, Carmona et al. 2003, Yli-Pelkonen and Kohl 2005, Bossellman 2009), it is intended to reflect the inclusive social and ecological concerns of the human ecosystem (Redman et al. 2004, Pickett and Grove 2009). Place focuses on the nature and availability of natural and cultural resources, the environmental constraints and hazards, the land form, and the built environment in specific locations. Biophysical aspects of place include things like soil, precipitation, the topographic drainage networks, the species that can grow there, the seasonal drivers of moisture and drought, temperature, and wind. They extend to the distribution of limiting resources over space and time, and the evolutionary and adaptive capacities embodied in biodiversity. These are the roster of features that an ecologist would want to know about ecosystems and their landscape contexts, and settlements are often located in places that are deemed favorable in ecological terms. Most common is a proximity to water in some way: coasts, bays and harbors, springs and oases, fall lines, and the like. The various features of place can be translated into ecosystem services and dissipers, which join social and biophysical perspectives. Water scarcity, as an aspect of place hybridizes the biophysical and social, whereas drought is a purely biophysical concept (Richter 2014). Economic investment and disinvestment in specific places is also key to the continuum of urbanity.

The evolution of garbage in Chinese villages is an example of the changing nature of local places that affects environmental quality. When rural villages and livelihoods were relatively distinct from cities, “waste” in villages was largely of biological origin. In fact, such materials were often perceived as resources. However, as material goods used in urban households increasingly are supplied by distant industries, packaging also increases in amount and changes in form. Styrofoam, flexible plastic wrapping, and hard plastic cases are now part of the waste stream in many villages. Rural people around the world have strong habits of reuse, but the part of the waste stream judged as useless is typically burned. That habit is now applied to the plastic packaging that comes in from mass retailers and with household appliances. New contaminants in smoke result, and are a potential health threat for residents who may be unaware of the hazard. Thus, connectivity can change the biogeochemistry of places, and with it human wellbeing.

Place is also invested with cultural values, as in “sense of place.” Places have spiritual, recreational, aesthetic, and historical value, among others (Millennium Ecosystem Assessment 2003). Places contain landmarks that orient people, historical reminders for groups and for individuals, symbols that express formal authority, and codes for rebellion (Shane 2005).

The biophysical and the social features of place share an increasing degree of integration across the continuum of urbanity. As suggested by teleconnections, places, whether clearly urban or seemingly rural, are no longer safely assumed to be distinct. The attributes of particular urban or rural places are now modified by choices made far away (Seto et al. 2012). This is perhaps the essence of contemporary urbanization. Although places are no longer independent, decisions affecting them are not made with full knowledge or even concern with the tripartite sustainability of places distant from the seats of decision making. This is true for decisions of government and of households.

An integrative example of the continuum

We have presented the continuum of urbanity as an abstract conceptual device above. To help make the framework concrete, we present an example that illustrates the involvement of the four process dimensions it comprises. The example originates in the interactions that follow on the shifting of many Asian diets toward carnivory. The details of this example appear in (Plowright et al. 2008, 2011). We will not repeat these citations throughout, however.

As the middle class grows in East and South Asia, people eat more meat. Consequently, Australia is becoming more and more a breadbasket and stockyard supporting this shift. The conversion of forest to agriculture has displaced populations of fruit bats or flying foxes, which have in the past lived in forests. These large flying mammals consume fruit, formerly available in a shifting, patchy pattern through time in Australia’s forest landscapes in response to patterns of drought and rain. The bats were thus nomadic in their native forest habitats. As forests are cleared or degraded by pig farming, the fruit bats relocate. Hence, fruit bats are now moving to cities, where they occupy permanent roosts. Because urbanites plant and irrigate fruit trees, the bats enjoy a reliable food supply in cities.

Bats are host to many viruses, and as they settle in urban areas, they have been a source of a virulent, sometimes fatal pulmonary disease of horses. This disease can sometimes jump to humans, and in an increasing number of cases is fatal. This example shows the power of teleconnections between urban sites, inhabited rural places, and wild or lightly managed lands, often extending between continents. The continuum of urbanity helps to understand such extensive effects of urban lifestyle, livelihood, connectivity, and aspects of place at various scales (Boone et al. 2014).

The continuum of urbanity, when combined with the globally important, spatially based model of urban megaregions, suggests that the contributions of ecological science must account for these novel, emerging, and spreading aspects of urbanization. There is a second ingredient in the successful contribution of ecology to urban sustainability: the recognition of the ripeness of
urban areas for transformation, whether they are new or old. How do ideas of sustainability intersect with the concepts of the urban megaregion and of the urbanity continuum to advance sustainability?

The Sustainable City

The call for sustainable development in the 1987 Brundtland Report introduced a model for urban systems beyond that of the industrial-city to sanitary-city transition (Grove 2009). That model is the Sustainability City, a social and political vision having two dimensions (Symes et al. 2005). On the first dimension, sustainable development does not foreclose the ability of people in the future to support themselves. This outcome is intergenerational equity. The second dimension of sustainability emphasizes that human wellbeing depends on three kinds of processes or pillars: ecological, social, and economic. Sustainable development would maintain the ecological services that support human wellbeing and provide the resources all humans require to live. But sustainable development would not harm disadvantaged social groups or those living in vulnerable places. In other words, development would be conducted in an equitable way (Naess 2001). Both the intergenerational and the process-oriented dimensions of sustainable development require an inclusive view about which people participate in the decision-making process, and about the social and biological processes that are vital to human wellbeing (Pincetl 2010, Boone and Fragkias 2012).

The sustainability worldview is increasingly applied to urban areas (Deelstra 1998, Naess 2001, Curwell et al. 2005, Jabareen 2006, Farr 2008, Grove 2009, Jenks and Jones 2010). It cannot mean that a city will be entirely self-sufficient or autotrophic. Rather, it suggests shaping a trajectory that increases sustainability. Urban sustainability is thus a relative concept (Childers et al. 2014). How can sustainability be enhanced in urban systems? What will guide the way through the global urban explosion, and the multitude of possible transformations cities can experience (Sanderson 2013, Pickett et al. 2014)? We discuss two hopeful pathways. One is sustainability planning (Beatley and Manning 1997), and the other is ecological urbanism (Pickett et al. 2013b; A. W. Spirn, unpublished manuscript).

Sustainability planning

Sustainability planning has been embraced by cities worldwide. Many examples come from cities participating in ICLEI (Local Governments for Sustainability, founded in 1990 as the International Council for Local Environmental Initiatives), an international, information-sharing, and activist organization. ICLEI’s founding followed close on the heels of the Brundtland Commission report (1987). ICLEI focuses on environmental improvements in cities, ranging from the largest of megacities to more modestly sized towns. ICLEI has identified seven topics for cities that wish to become more sustainable: (1) biodiversity, (2) climate, (3) ecomobility, (4) management instruments for environmental accounting, (5) sustainable procurement procedures, (6) building sustainable cities, and (7) water. Within these broad topics, a variety of familiar issues appear, including climate adaptation and vulnerability, resilience, energy efficiency, quality of air and water, economic viability, social equity, reduction of greenhouse gasses, and design and management of green spaces.

The sustainability plans of many cities mirror the ICLEI agenda. An example is the City of Baltimore Sustainability Plan, which originated through an open, inclusive social process that generated input from some 1200 Baltimore residents from all areas of the city, all social groups, and all economic strata. The plan has seven components: (1) cleanliness, (2) pollution prevention, (3) resource conservation, (4) greening, (5) transportation, (6) education and awareness, and (7) green economy (Baltimore City 2009). The New York City PlaNYC (Mayor’s Office of Long-term Planning and Sustainability 2015) has several similarities. In China, the Beijing 2004–2020 master plan (Beijing Municipal Institute of City Planning and Design 2004) shares many positive environmental features with ICLEI proposals. Notably, the plan gives high priority to ecological “redlining” in which areas are to be set aside from development to achieve ecological benefits. The plan also recognizes the need to link with the rural villages and with the other major nodes in the Beijing-Tianjin-Hebei megaregion, a reflection of the growing importance of the Chinese policy of urban-rural integration (Ye 2009). Economic development remains an important motivation, although the attention to ecological aspects of the plan reflects the shifting emphasis of the central government toward sustainability (Pan 2012, Bai et al. 2014). However, experience demonstrates that many of the “green” areas identified in the 2004 plan have already been overtaken by the extraordinary rate of growth of Beijing.

Ecological urbanism

A second way to move toward sustainability is to employ design strategies and approaches that are summarized as ecological urbanism. Ecological urbanism takes into account ecological structures and processes, or incorporates knowledge of ecological science into urban design. Landscape architect Anne Whiston Spirn (unpublished manuscript) says that ecological urbanism “…wedds the theory and practice of city design and planning, as a means of adaptation, with the insights of ecology—the study of the relationships between living organisms and their environment and
the processes that shape both—and other environmental disciplines, such as climatology, hydrology, geography, psychology, history, and art. Ecological urbanism has an aesthetic dimension, but it is not a style; the works of its practitioners may be radically different in appearance even though based on the same principles.” Importantly, she and other scholars and practitioners of ecologically informed urban design insist that cities also provide meaning and delight (McGrath 2013, Nassauer 2013; A. W. Spirn, unpublished manuscript).

What principles might drive more ecologically informed urban design? Spirn’s (1984) rich exposition can be summarized in this way, quoting, but converted to bullets for emphasis:

- cities are part of the natural world;
- cities are habitats;
- cities are ecosystems;
- urban ecosystems are dynamic and interconnected;
- every city has a deep, enduring context; and
- urban design is a tool of human adaptation.

These principles are extraordinarily consonant with the perspective that emerges from the biologically based, evolutionarily informed, science of ecology (Cadenasso and Pickett 2008). But the view is also consistent with urban ecology’s more recent attempts to integrate with the social sciences (Grimm et al. 2000, Collins et al. 2011; also see Box 1) and to connect with ethics and humanities (Rozzi et al. 2014). These principles suggest that designing without explicit consideration of the ecological context and processes within urban systems will leave cities incomplete, hobbled, and vulnerable (Pickett et al. 2013a). In other words, they will remain unsustainable. The principles of ecological urbanism suggest a way past crisis.

**Conclusion: a New Synthetic Framework to Support the Science of Urban Sustainability**

The received frameworks of urban change and form, derived from 20th-century experience in the Global North, are inadequate to understand and work with the immense and diverse changes in the urban realm worldwide. If ecologists continue to employ the assumptions embodied in the industrial urban development model, or the spatial expectations of the megalopolis model, their contributions to urban research and application may be limited. We have noted how the industrial development model fails now even in the Global North, where postindustrial changes in cities continue, shifting the spatial, governance, resource-use, financial, and environmental relationships of extensive urban systems. The model likewise falls short in the Global South and East, where economies, migration patterns, rapid communication without a wired grid, and new spatial forms of urbanization suggest very different fundamental assumptions than the Northern model. New juxtapositions of city, suburban, exurban, agricultural, and wild patch types and urban functions are common, and the sequences of change are also novel in many Global Southern and Eastern regions. In other words, the theoretical paradigms under which the biological ecology of urbanization has traditionally been examined may be in crisis. Indeed, such intellectual crisis is matched by the practical crises of intensifying urban pollution, failure to invest in renewed or appropriate infrastructure, the migration of new residents to informal settlements and slums, and in general, the need to make urban settlements of all sizes and forms more ecologically and socially supportive.

The practical challenges and intellectual novelty that will be required to deal with the changing reality of urbanization around the world call for new frameworks. This paper has summarized two candidate frameworks, and we propose a synthesis to support future research and application. One is the concept of the urban megaregion (Fig. 1), and the other is the continuum of urbanity (Fig. 5). These frameworks bring together concepts and insights with deep roots in a variety of disciplines. Their joint contribution to a framework for explanation and integration of biological ecology into the urban realm is new.

The first framework emphasizes the spatial extensiveness of cities, regions, and new spatial forms of urbanization. The megaregion model, for example, reflects the need to make urban settlements of all sizes and forms more ecologically and socially supportive. The second framework, the continuum of urbanity, is designed to support future research and application. One is the concept of the urban megaregion (Fig. 1), and the other is the continuum of urbanity (Fig. 5). These frameworks bring together concepts and insights with deep roots in a variety of disciplines. Their joint contribution to a framework for explanation and integration of biological ecology into the urban realm is new.

**Box 1**

**Beijing Urban Ecological Research and Its Applications**

Beijing urban ecological research started from the 1980s, when Ma and Wang (1984) pioneered the concept of social-economic-natural complex ecosystems (SENCE). This concept underscores the reciprocal interactions between coupled human and natural systems, and calls for integrative biophysical and socio-economic understanding of cities. With the establishment of the Beijing Urban Ecosystem Research Station, so far only stations within the Chinese Ecological Research Network (CERN) that specifically studies urban ecology, there is a growing body of integrated research in Beijing urban ecosystems, ranging from urbanization patterns and processes, ecosystem processes, ecosystem services and ecological risks, and urban sustainability. Notably, Beijing research on ecosystem structure, process, and service has been used as the basis for stormwater management, and to develop the land use master plan of Beijing (2004–2020).
facets of urban megaregions are more porous, interdigitated, and linked than the precedent models of the centered metropolis or even the linear megaregion, originally indicated. Furthermore, the megaregion avoids assumptions of industrial motivation for urbanization, and accepts consumption, service, and convenience as processes contributing to the more expanded and heterogeneous settlement forms. Each of these precedent concepts has been modified and expanded to account for changes on the ground. However, to cement and highlight the increased spatial, organizational, and relational complexity of urbanized and urbanizing regions, the urban megaregion serves well.

The second framework is the continuum of urbanity, which emphasizes four conceptual dimensions along which urbanization changes the physical and social features of regional landscapes. The degree of urbanity is expressed through livelihood, lifestyle, connectivity at several scales including the global, and the attributes of specific places as they constrain or respond to the first three dimensions. The differing degrees of urbanity represent the kinds of interactions and process relationships that take place across the extensive and porous spatial mosaic represented by the urban megaregion. Thus, the two frameworks together provide the conceptual space in which both the quantities and the qualities of urbanization and urbanized regions can be addressed. The two frameworks are complementary and vetted in the literature (Boone et al. 2014, Harrison and Hoyler 2014).

Existing approaches to the study of urban systems provide the tools to flesh out the specifics of urban megaregions and their internal and global relationships. These two frameworks do not replace, but rather give a home to these familiar urban research approaches: patch dynamics, watersheds, land cover mapping, land use classification, remote sensing, human demography and migration, political ecology, ecological economics, biogeochemistry, metabolism and material balance studies, and ecology in/ecology of cities, among others.

By indicating how insights about social-ecological structures and processes from both the United States and China fit within the arguments of this paper, we hope to have suggested that the emerging megaregion/continuum of urbanity frameworks are usefully comprehensive and inclusive. Indeed, both “developed” and “developing” countries experience continuing change in their urban realms and in the significant interaction of the nominally urban with the nominally rural. There is no end point to urbanization, and there are no isolated urban places. The dynamics and spatiality of urban patterns and urban processes are shared by the all locations in the global urban enterprise.

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