On Urban Social-Ecological Systems, Sustainability and Resilience- Implications for SDGs and Development of Indicators[1]

We are entering an era where cities increasingly are becoming the central nexus of the relationship between people and nature, where cities dominate demands for ecosystem services and are main sources of global environmental impacts. Given the accelerated and rapid changes in urbanizing regions across the planet, projected to continue for the next 4 to 5 decades, there is an urgent need to focus on urbanization and analyse how the urbanization process itself can be made more sustainable.

A recent global assessment[2] of urbanization and links to biodiversity and ecosystem services identified the following five trends:

1. Urban areas are expanding faster than urban populations. If current trends continue, between 2000 and 2030 urban land cover is expected to triple, while urban populations are expected to nearly double. Most of the growth is expected to happen in small and medium-sized cities, not in megacities.

2. Urban areas modify their local and regional climate through the urban heat island effect and by altering precipitation patterns, which together will have significant impacts on local and regional net primary production, biodiversity and ecosystem functions.

3. Urban expansion will heavily draw on natural resources, including water, on a global scale, and will often consume prime agricultural land, with knock-on effects on biodiversity and ecosystem services elsewhere.

4. Urban land expansion is occurring rapidly in areas adjacent to biodiversity hotspots, and faster in low-elevation, biodiversity-rich coastal zones than in other areas.

5. Future urban expansion will mainly occur in regions of limited economic and institutional capacity, which will constrain management of biodiversity and ecosystem services. Half the increase in urban land across the world over the next 20 years will occur in Asia, with the most extensive patterns of change expected to take place in India and China.

The assessment also concluded that approximately 60 percent of the urban land projected to be present in 2030 is forecast to be built just in the period 2000-2030[3]. Urbanization thus not only presents challenges for global sustainability, but also

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[1] This note is written by Thomas Elmqvist and based on multidisciplinary work carried out in the Cities and biodiversity outlook project (CBO) initiated by CBD. For further information see www.cbd.int and www.cbobook.org

[2] Elmqvist et al. (eds.), 2013. Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment, SpringerOpen, DOI 10.1007/978-94-007-7088-1_21. The assessment requested in decision x/22 of COP10 of CBD in Nagoya, October 2010.

[3] Fragkias et al. 2013. A Synthesis of Global Urbanization Projections In: T. Elmqvist et al. (eds.), 2013. Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment, SpringerOpen, DOI 10.1007/978-94-007-7088-1_21

numerous opportunities. In the next two to three decades, we have unprecedented chances to vastly improve global sustainability through designing systems for increased resource efficiency, as well as for exploring how cities can be responsible stewards of biodiversity and ecosystem services both within and beyond city boundaries.

A social-technological approach has, up until now, been a traditional way of analyzing urban complexity[4], and in this context many have struggled to define exactly what is meant by a city. There is an emerging framework of cities as complex social-ecological systems, since cities include much more than a particular density of people or area covered by human-made structures. A social-ecological approach[5] will increasingly be necessary to apply in order to succeed in enhancing human well-being in urban areas in the face of new and complex challenges such as climate change, migration, and shifting and globalized economic investment. We will need a vigorous debate on how the many opportunities created by urbanization could result in innovative policy for more sustainable development on a global scale. This debate should explore the imperative of reconnecting cities to the biosphere, the social-ecological foundation of cities and their sustainability and how this urban ecological embedding may be facilitated through a new and bold urban praxis.

To just give one example, and as highlighted in the Cities and Biodiversity Outlook Action and Policy (Secretariat of the Convention on Biological Diversity 2012)[6], urban biodiversity and ecosystem services can play important roles in mitigating and adapting to climate change both in developed and developing urban regions. Urban green spaces, ranging from parks to residential lawns and roof gardens, contribute to climate-change adaptation in several ways: (1) trees can contribute to adaptation by providing more shade and cooling, thereby reducing overall energy consumption. The total amount of energy savings depends on many factors, including the species, size, abundance, and location of trees. In most cities around the world, there is abundant opportunity to increase urban vegetation. (2) vegetation and green roofs can significantly reduce both peak flow rates and total runoff volume of rainwater by storing it in plants and substrate and releasing it back to the atmosphere through evapotranspiration. Functional watersheds also play a crucial role in mitigating and adapting to climate change. Watersheds provide access to safe water for drinking and irrigation, which is especially critical given how climate change is disrupting precipitation cycles and historical river flows and groundwater levels. Preserving rather than draining and paving over wetlands can allow for the absorption of excess rainfall and buffer against coastal flooding. As the effects of climate change intensify—putting unprecedented pressure on urban infrastructure such as storm

[4] Geels, F. (2011). Role of cities in technological transitions. In H. Bulkeley (Ed.), Cities and low carbon transitions (p. 3-28). London/New York: Routledge/Taylor and Francis Group.
[5] Berkes, F., & Folke, C. (Eds.). (1998). Linking social and ecological systems: Management practices and social mechanisms for building resilience . Cambridge: Cambridge University Press.
[6] Secretariat of the Convention on Biological Diversity (2012) Cities and Biodiversity Outlook. Montreal, 64 pages. http://www.cbd.int/en/subnational/partners-and-initiatives/cbo

drainage, seawalls, and levees—ecosystem-based adaptation is worth far more than the nominal cost of ecosystem preservation[7].

As human dominance of ecosystems spread across the globe, humankind must become more proactive not only in trying to preserve components of earlier ecosystems and services that they displace, but also in imagining and building whole new kinds of ecosystems that allow for a reconciliation between human development and biodiversity. Populations and assemblages of species that evolve under urban conditions may well represent what holds for much of Earth's terrestrial biodiversity in the future.

How urban planning, through actively incorporating biodiversity and ecosystem services in urban development and design, can address multiple challenges related to human health, climate change adaptation and disaster risk reduction need to be reflected in the SDGs. However, it is also of paramount importance that the overarching question: what actually constitutes urban sustainability—particularly in relation to various spatial scales, is seriously addressed. This also, as discussed below, needs to include a rethinking of the concepts of resilience and transformations.

Rethinking urban sustainability, resilience and transformation

Although local governments often aim to optimize resource use in cities, increase efficiency, and minimize waste, cities can never become fully self-sufficient. Individual cities cannot therefore be considered "sustainable" without acknowledging and accounting for their dependence on ecosystems, resources and populations from other regions around the world[8].

However, the research and application of urban sustainability and urban resilience have until now rarely been applied beyond city boundaries and often been constrained to either single or narrowly defined issues (e.g., population, climate, energy, water)[8]. Consequently, there is a need to revisit the concept of sustainability, as its narrow definition and application may not only be insufficient but can also result in unintended consequences, such as the "lock-in" of undesirable urban development trajectories[1].

An example is represented by one of the most critical resources, the provision of freshwater. Urban areas depend on freshwater availability for residential, industrial, and commercial purposes; yet, they also affect the quality and amount of freshwater available to them. Water availability is likely to be a serious problem in most cities in semiarid and arid climates. Currently 150 million people already live in cities with perennial water shortage. By 2050, population growth is projected to increase this number to almost a billion people, and climate change is projected to cause water shortage for an additional 100 million urbanites. There are strong incentives for cities

[7] Solecki, W and Marcotullio, P. 2013. Climate change and urban biodiversity vulnerability. In: T. Elmqvist et al. (eds.), Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment, SpringerOpen. DOI 10.1007/978-94-007-7088-1_25,

[8] Seitzinger, S et al. 2012. Planetary Stewardship in an Urbanizing World: Beyond City Limits. AMBIO 41:787–794 DOI 10.1007/s13280-012-0353-7

to engage in active and better management of large and sometimes distant watersheds to ensure the delivery of sufficient quantities and qualities of freshwater.

Hence, a more appropriate conceptualization of urban sustainability is one that incorporates a complex social-ecological systems perspective of urban areas and their global hinterlands, and one that recognizes that urban areas are embedded in, and are significant parts of, the operation of the biosphere. The focus is not just on sustainability goals or aspirations, but also on resilience and transformations as components of the urbanization process.

Sustainability and resilience

An important question in this context is how the two concepts resilience and sustainability are related? Do they mean approximately the same thing or are they distinctly different and can misunderstandings lead to undesired outcomes? The classic definition of sustainable development focuses on how to manage current resources in a way that guarantees the welfare of current and future generations (see Table 1). However, as argued above, urban sustainability needs to incorporate a complex systems perspective of urban areas and their global hinterlands, and consider the resilience of the processes potentially promoting sustainable urbanization.

While sustainable development is inherently normative and positive, this may not necessarily be true for the resilience concept[1]. The desirability of specified resilience (Table 1) in particular, depends on careful analysis of resilience "of what, to what" and to "whom" [9] since many examples can be found of highly resilient systems (e.g. oppressive political systems) locked into an undesirable system configuration or state. Recently, sustainability has also been viewed as a form of development that fosters adaptive and transformative capabilities and creates opportunities to maintain equitable long-term prosperity in complex, interlinked social, economic and ecological systems[1]. With such a definition resilience and sustainability come together and resilience can be seen as a necessary approach (non-normative process) to meet the challenges of sustainable development (normative goal) [10]. Otherwise the apparent large overlap between the two concepts will not serve us well and make both concepts weak and lack of meaning.

Table 1. Definition of concepts[2]

Sustainability	**Manage resources in a way that guarantees welfare and promotes equity of current and future generations**
Resilience	The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure and feedbacks, and therefore identity, i.e. capacity

[9] Carpenter, S., Walker, B., Anderies, J. M., and Abel, N. 2001. From metaphor to measurement: Resilience of what to what? Ecosystems 4(8): 765–781.

[10] Chelleri L and Olazabal M, 2012. Multidisciplinary perspectives on urban resilience. BC3, Basque Centre for Climate Change. Bilbao, Spain. ISBN: 978-84-695-6025-9a

	to change in order to maintain the same identity
General resilience	The resilience of a system to all kinds of shocks, including novel ones
Specified resilience	The resilience "of what, to what"; resilience of some particular part of a system, related to a particular control variable, to one or more identified kinds of shocks
Transformation	The capacity to transform the stability landscape itself in order to become a different kind of system, to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable.

When most people think of urban resilience, it is generally in the context of response to sudden impacts, such as a hazard or disaster recovery. However, the resilience concept goes far beyond recovery from single disturbances. Resilience is a multidisciplinary concept that explores persistence, recovery, and the adaptive and transformative capacities of interlinked social and ecological systems and subsystems [11] (Table 1).

At a first glance, building resilience seem counterintuitive to transitions, given the definition in Table 1 of transformability as the capacity to transform and become a different kind of system, to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable. Key to understanding the role of transformability in resilience is to distinguish between specified and general resilience and to remember that systems have multiple scale levels. The contradiction is real when discussing specified resilience at a specific scale level, but when analyzing general resilience of a nested system, transformation at lower scale levels are often necessary to maintain resilience on a larger scale [12].

Resilience, governance and urban planning

It has often been pointed out that one of the basic tenets of resilience and systems thinking is that a too strong emphasis on efficiency (maximising outputs) can erode resilience through a deliberate reduction in redundancy and connectivity[13]. The loss of redundancy and connectivity might create vulnerabilities in the urban system as a result of an increased dependence on a few resource sources and the entire system might become unstable having insufficient overlap in functions. This has large

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11 Biggs, R, M Schlüter, D Biggs, EL Bohensky, S Burnsilver, G Cundill, V Dakos, T Daw, L Evans, K Kotschy, A Leitch, C Meek, A Quinlan, C Raudsepp-Hearne, M Robards, ML Schoon, L Schultz, and PC West. 2012. Towards principles for enhancing the resilience of ecosystem services. Annual Review of Environment and Resources 37: 421-448.

12 Allen, T. F. H. & Hoekstra, T. W. (1992). *Toward a unified ecology.* New York: Columbia University Press.
Wu, J. & Loucks, O. L. (1995). From balance of nature to hierarchical patch dynamics: a paradigm shift in ecology. *Quarterly Review of Biology* 70: 439-466.

13 Janssen, M. A., Bodin, O., Anderies, J. M., Elmqvist, T., Ernstson, H., McAllister, R. R. J., Olsson, P., and Ryan, P. 2006. Toward a network perspective of the study of resilience in social-ecological systems. Ecology and Society 11(1).

consequences for the institutional structure and governance of resources and represent challenges in urban planning.

While planning theory thus far has paid surprisingly little attention to human-nature relations[14], planning practitioners see insights from resilience thinking as providing a new language and metaphors for the dynamics of change and new tools and methods for analysis and synthesis. Furthermore, a resilience approach confronts modes of governance based on assumptions of predictability and controllability with a mode based on dynamics and non-linearity. This is an emerging field where new, innovative means of planning that deal with urban complexity and sustaining urban ecosystem services are needed. However, resilience thinking and social-ecological theory provide planning with little guidance in prioritizing or addressing tradeoffs between different strategies, highlighting the inherently political character of urban governance[13].

Summary: lessons for SDGs and development of appropriate indicators

Based on this overview, it is clear that urban sustainability and resilience thinking, and policies derived from this thinking, must, to a much greater extent, address scales and consider urban teleconnections[15], i.e., urban dependence and impacts on distant populations and ecosystems. There is an apparent danger of applying too narrow an urban scale for these types of policies, since, for example, building (desired) resilience in one city may likely lead to erosion of resilience or create undesired resilience elsewhere.

In developing the SDGs and related indicators it is important to address:

1. the larger open urban system including the impact and dependence on distant ecosystems connected through multiple teleconnections.
2. that building sustainability through resilience entails investing in redundancy in governance and institutions at the local scale and engaging in collaboration across a global system of cities to create a framework to manage resource chains. Resilience analyses can help us understand some of the true costs of sustainability, i.e. investing in redundancy and cross scale interactions
3. that it is necessary that indicators capture to what extent urban regions provide stewardship of all the distant ecosystems on which they depend. But it is not only important to develop such more integrated indicators, there is also a need of more scalable indicators. Using indicators that make sense on a local scale and then possible to scale up on a regional and global scale opens up the possibility to engage local stakeholder, citizen groups, indigenous groups and many other knowledge holders in the monitoring and reporting on the SDGs.

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14 Wilkinson C, 2012. Social-ecological resilience insights and issues for planning theory. Planning Theory 11(2):148-.-169.

15 Seto, K.C., A. Reenberg, C.G. Boone, M. Fragkias, D. Haase, T. Langanke, P. Marcotullio, D.K. Munroe, et al. 2012. Urban land teleconnections and sustainability. Proceedings of the National Academy of Sciences of the United States of America 109: 7687–7692. doi:10.1073/pnas.1117622109.