

## COMMENT OPEN



## Urbanization in and for the Anthropocene

T. Elmqvist<sup>1</sup>✉, E. Andersson<sup>1,2</sup>, T. McPhearson<sup>1,3,4</sup>, X. Bai<sup>5</sup>, L. Bettencourt<sup>6</sup>, E. Brondizio<sup>7</sup>, J. Colding<sup>8,9</sup>, G. Daily<sup>10</sup>, C. Folke<sup>1,8</sup>, N. Grimm<sup>11</sup>, D. Haase<sup>12</sup>, D. Ospina<sup>1,8</sup>, S. Parnell<sup>13</sup>, S. Polasky<sup>14</sup>, K. C. Seto<sup>15</sup> and S. Van Der Leeuw<sup>16</sup>

Key insights on needs in urban regional governance - Global urbanization (the increasing concentration in urban settlements of the increasing world population), is a driver and accelerator of shifts in diversity, new cross-scale interactions, decoupling from ecological processes, increasing risk and exposure to shocks. Responding to the challenges of urbanization demands fresh commitments to a city–regional perspective in ways that are explicitly embedded in the Anthropocene bio- techno- and noospheres, to extend existing understanding of the city–nature nexus and regional scale. Three key dimensions of cities that constrain or enable constructive, cross scale responses to disturbances and extreme events include 1) shifting diversity, 2) shifting connectivity and modularity, and 3) shifting complexity. These three dimensions are characteristic of current urban processes and offer potential intervention points for local to global action.

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## URBANIZATION IN THE ANTHROPOCENE

We live in turbulent times—the Anthropocene—where rapid changes are occurring in biophysical conditions driven by accelerating growth in human activity. New risks emerge from interactions at the interface of multiple systems including climatic, ecological, political, social, institutional, infrastructural, financial, and technological systems<sup>1–4</sup>. In a globalized world characterized by shifting patterns of inequality, new cross-scale interactions, and decoupling from ecological processes<sup>5–8</sup>, altered disturbance regimes increasingly lead to shocks that were previously contained within a geographic area or a sector, but now are becoming globally contagious<sup>9,10</sup>. Global urbanization (the increasing concentration in urban settlements of the increasing world population), is a driver and accelerator of many of these processes<sup>11</sup>.

The effects of multiple interacting changes that can be traced to the expansion of cities, generates new and extreme global vulnerabilities<sup>12,13</sup>, making global urban change a frontier of science for sustainability<sup>14,15</sup>. For example, cities are responsible for ~70% of global CO<sub>2</sub> emissions from final energy use, but are disproportionately and increasingly exposed to the impacts of climate change, since 90% of urban areas—and the majority of the world's population—are situated on coastlines<sup>16</sup>. A recent study shows that 339 million people live on deltas throughout the world. Of these 31 million people are living in the 100-year storm surge floodplains, 92% of whom live in developing or least-developed economies<sup>17</sup>. Further, in coming decades, climate-change driven migration is expected to increase dramatically. When migrants settle in larger cities they add to existing challenges, particularly in developing countries often unable to provide basic infrastructure or social protection in response to accelerated growth<sup>18–20</sup>. While some cities are already shrinking,

the overall challenge is one of expansion, with the global urban footprint up by up to 1.3 million square kilometers between 2015 and 2050 (an increase of 171 percent over the 2015 figure)<sup>21</sup>. Given the overarching dominance of urban growth, we here consider ways in which interlinked social, ecological and technological system diversity and interlinkages support or hinder urban development and influence potential for cities to be positive drivers of local and global sustainability transformation. We argue that to position cities at the core of planetary change, better understanding of the city–regional scale is key.

Although urbanization has existed for millennia, in its present form it functions as an accelerating aspect of the Anthropocene. What is important is not just that cities and their hinterlands are interdependent but that the form of their interdependencies are increasingly complex and significant globally—as the COVID-19 pandemic has recently demonstrated<sup>22</sup>. Urban areas are dependent on extracting external, teleconnected resources that empower cities as economic, political, and cultural hubs, that in turn drive global flows of material, energy, and information<sup>23,24</sup>. A recent study shows that human energy expenditure since 1950 (~22 zetajoules (ZJ)), particularly related to fossil fuels, exceeds that across the entire prior 11,700 years of the Holocene (~14.6 ZJ)<sup>25</sup>. Urban resource demand is influenced by continuous changes in urban stocks such as population size, infrastructural and housing density, consumption patterns and lifestyles, and urban policy and management decisions<sup>26</sup>. Disconnection of cities from their hinterlands tends to lead to the undervaluation of remote nature—and associated deforestation and other habitat destruction, agricultural intensification, climate change, and the wildlife trade—are driving biodiversity loss<sup>27,28</sup>.

Uniform approaches to making technology and urban infrastructure ever more efficient are often reducing the redundancy

<sup>1</sup>Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden. <sup>2</sup>Unit for Environmental Sciences, North-West University, Potchefstroom, South Africa. <sup>3</sup>Urban Systems Lab, The New School, New York, NY, USA. <sup>4</sup>Cary Institute of Ecosystem Studies, Millbrook, NY, USA. <sup>5</sup>Fenner School of Environment & Society, Australian National University, Canberra, Australia. <sup>6</sup>Mansueto Institute for Urban Innovation & Department of Ecology and Evolution, University of Chicago, Chicago, IL, USA. <sup>7</sup>Department of Anthropology, Indiana University, Bloomington, Indiana, USA. <sup>8</sup>The Beijer Institute, The Royal Swedish Academy of Sciences, Stockholm, Sweden. <sup>9</sup>Department of Building Engineering, Energy Systems and Sustainability Science, University of Gävle, Gävle, Sweden. <sup>10</sup>Natural Capital Project, Department of Biology and Woods Institute, Stanford University, Stanford, CA, USA. <sup>11</sup>School of Life Sciences, Arizona State University, Tempe, AZ, USA. <sup>12</sup>Department of Geography, Humboldt University, Berlin, and Helmholtz Centre for Environmental Research - UFZ, Leipzig, Germany. <sup>13</sup>School of Geography, University of Bristol, UK and African Centre for Cities, University of Cape Town, Cape Town, South Africa. <sup>14</sup>Department of Applied Economics, University of Minnesota, Minneapolis, MN, USA. <sup>15</sup>Yale School of the Environment, Yale University, New Haven, CT, USA. <sup>16</sup>School of Human Evolution and Social Change, Arizona State University, Tempe, AZ, USA. ✉email: [thomas.elmqvist@su.se](mailto:thomas.elmqvist@su.se)

needed for resilience in the face of global change and extreme events<sup>15,29</sup>. Innovating and transitioning societies along more sustainable development pathways that can reverse changes brought about by the initial onset of the Anthropocene is set in the context of a reality in which strategic decision making in and for cities is challenged by obdurate governance systems<sup>30</sup>. These have yet to embrace polycentric<sup>31</sup>, multi-scale<sup>32</sup>, and other governance innovations already articulated. In our current urban Social-Ecological-Technological Systems (SETS)<sup>33</sup>, governance is characterized by decentralization and compartmentalization, intensively managed ecosystems<sup>34</sup> and activities increasingly mediated through technologies and through support from socioeconomic infrastructures.

Cities have long been known to depend on their natural hinterlands<sup>35,36</sup>, but an increase in global connectivity and redundancy of supply systems have masked this dependence, particularly consequences of local resource exploitation, through long and complicated global supply chains. Now more than ever, flexible multi scale urban management that links the points of consumption to the extraction, production, and distribution of goods, is essential. It is well established that actions at the local scale can add up to positive or negative impacts at regional or global scales, potentially affecting distant areas through investment and political incentives as well as urban worldviews and lifestyles at an increasingly rapid pace<sup>7,13,24,37</sup>. In this context, envisioning and implementing ways to extend urban governance and sustainability initiatives beyond the local is a critical challenge<sup>38</sup>. In parallel with cities taking on more global responsibilities, global decision-making and linked institutions need to allow for local, polycentric, bottom-up embedded solutions and governance approaches to fit the cultural, fiscal, economic, and geographic contexts in which they are to function in order to mitigate “environmental reductionism” in society<sup>39</sup>.

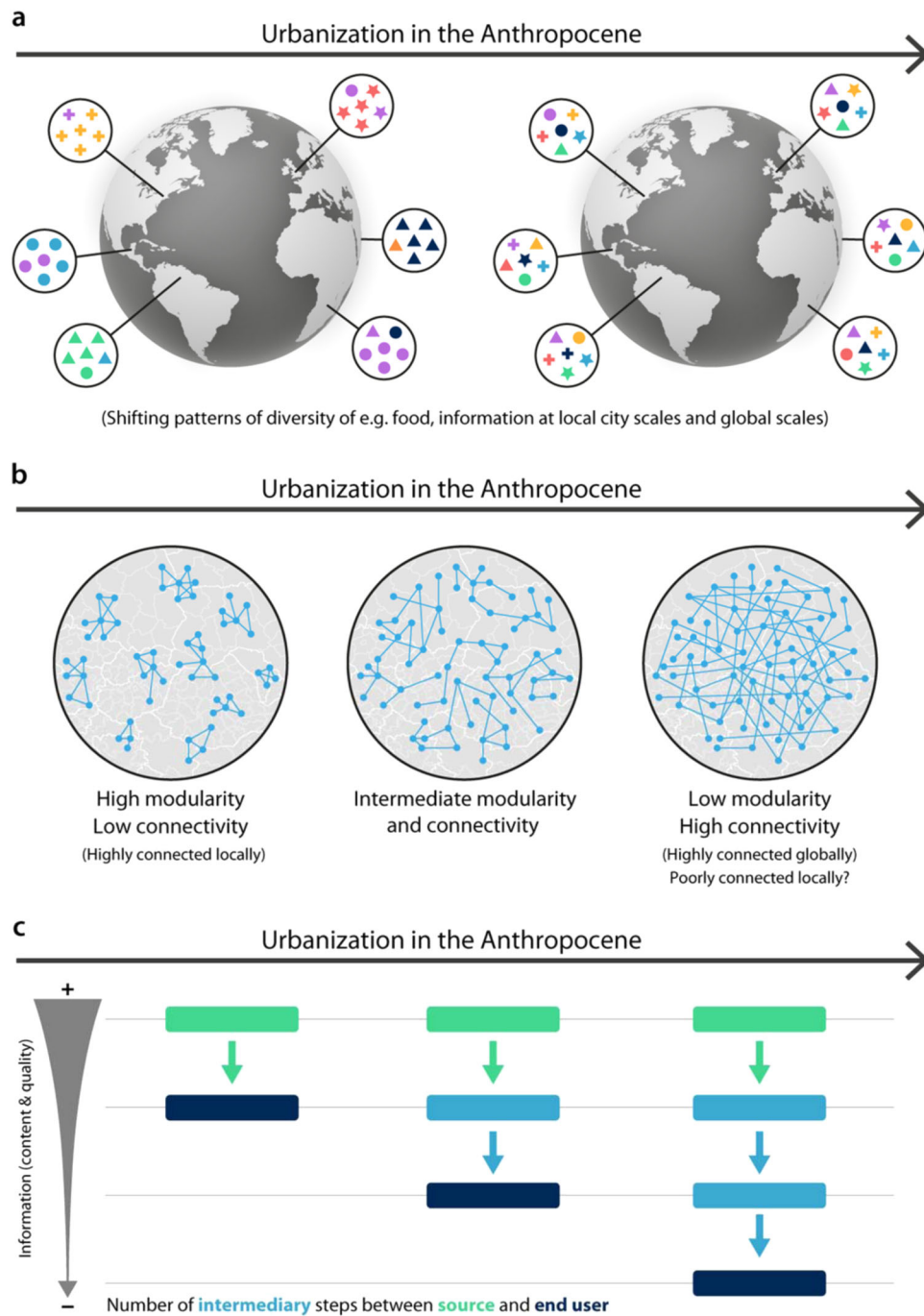
We ask a critical question: What constrains or enables constructive, cross scale responses to disturbances and extreme events, and over the long term, transformations towards more sustainable and resilient cities? To address this complex question we focus on three key dimensions of cities as embedded in the Anthropocene bio-, techno- and noosphere to examine fundamental drivers and opportunities for sustainability and resilience solutions: 1) shifting diversity, 2) shifting connectivity and modularity, and 3) shifting complexity. We describe these three urbanization dimensions as especially characteristic of current processes. Additionally these dimensions offer potential intervention points for local to global action (Fig. 1a–c)

1. Shifting diversity—We see a recurring pattern of shifting diversity (Fig. 1a) with increased diversity at local scales and increased homogeneity at global scales. One example is the global food system<sup>8</sup>: although local and regional crop diversity have increased, the same kinds of bulk crops are grown on all continents<sup>40</sup>. This replication of local and regional diversity is further amplified by intensive long-distance trade, resulting in an increasingly diverse but standardized set of food commodities being available locally<sup>8</sup>. Estimates suggest that 20% of global cropland is being allocated to the production of commodities that are consumed in another country<sup>41</sup>, with significant impacts on deforestation levels<sup>42</sup>, masking the erosion of overall diversity. Similarly, migration in the form of urban–rural or international population movements by relatively privileged migrants spread environmentally impactful consumption habits around the world<sup>43</sup>.

At the same time, cities are increasingly shifting away from analog ways of interacting, gathering data, and even decision-making towards digital alternatives with reduced redundancy and increasingly (fragile) reliance on a narrow range of energy and communication networks. While

increasingly prolific and diverse, digitalization will generate both opportunities but also may create barriers to data access, and can even decrease diversity, such as when transportation, information, communication, and other critical urban infrastructure systems rely on a single systems, internet connectivity, to function. Such overreliance on single systems with impacts on myriad infrastructure systems will generate new reliability and security risks with as yet unknown potential consequences for urban resident life, not least when digital systems are threatened by climate or other extreme events and may stop functioning altogether<sup>44,45</sup>.

2. Shifting connectivity and modularity—We illustrate (Fig. 1b) how human activities, not least in urban regions, increase the spatial dimensions of connectivity and change modularity<sup>15</sup>. Although the drivers of these changes are not new (e.g., trade, transport, technology and consumption), the speed and scale at which they occur are unprecedented<sup>8</sup>. As urbanization proceeds (left to right in Fig. 1b), modularity is reduced and connectivity is increased, which has been argued to, after a breaking point, greatly reduce resilience of the system<sup>46</sup>. With low modularity in a highly connected system, responses become more synchronized. For example Tu et al.<sup>47</sup>, suggest that the resilience of the global food system has declined over the past decades due to increased interconnectedness and reduced modularity. They argue that, due to the structural characteristics of the food trade network, additional trade links will further erode the resilience of the global food system. In an economically, digitally, socially, and ecologically connected global network that is also connecting at faster and faster rates, several new and compounded risks emerge associated with an ever more hyper-cohesive world (e.g., climate change induced shocks occurring simultaneously with new global pandemics). A shift back to some intermediate form of connectivity and modularity would be needed to restore resilience to the system<sup>47</sup>. Such modularity that we focus on here can, for example, be promoted by institutions that allow for bottom-up, self-organized, and locally evolved management solutions that to a higher degree draw on civil society actors<sup>48</sup>. On the other hand, the experience of COVID-19 pandemic also shows that networks within and across cities can help enhance the functional resilience of the city in the face of major disasters<sup>49</sup>. For example, there have been large flows of aid through sister city networks across borders, for example from other cities to Chinese cities, but also later reciprocated strongly once these cities started to recover. This points to the need for a greater coordination and collaboration across cities, which can help turn the vulnerability of high connectivity into sources of resilience<sup>49</sup>.
3. Shifting complexity—We illustrate (Fig. 1c) the increasing physical and cognitive distance between (re)sources and consumers as well as actions and outcomes. In addition to diversity and the overall anatomy of local to global linkages, this point concerns the complexity of the linkages themselves. As cities grow, they expand in complexity<sup>50</sup>, both internally and in how they are embedded in regional to global systems. Globalization, advancing technological development, commodification, and sectoral compartmentalization are adding a growing number of intermediate steps<sup>51</sup> between people and the resources they use, such as natural resources, information, and technology. This ever-greater cognitive distance makes it increasingly challenging for people to know the impacts of their consumptive decisions and also to design effective institutions to govern economic exchange and human interaction (e.g., the value–action gap<sup>52,53</sup>).



**Fig. 1** Characteristics of urbanization in the Anthropocene over time. **a** Shifting diversity—colors and shapes of symbols illustrating how diversity of e.g. food and sources of information and knowledge has increased over time at the city level, while becoming more and more homogenized at the global level. **b** Shifting connectivity and modularity—in the Anthropocene spatial dimensions of modularity tends to decrease and connectivity increase over time. **c** Shifting complexity—in the Anthropocene development also tends to increase complexity and number of layers of actors/agents/information etc. between source and end user. For discussion see text.

Ecosystem service use is increasingly becoming commodified and commercialized, while information networks are increasingly global (and thus often far from what people can experience directly), and health services and transportation are increasingly provided by interacting, specialized actors and structures. For example, small household appliances often have long supply chains associated with their production, and there is little transparency regarding the sustainability of any production process along the chain. It can be challenging, almost impossible,

to make positive choices for sustainable consumption with so many information steps within each step to understand or have information on to inform consumption practices. The subsystems interact as well, creating dizzying complexity for anyone trying to make sense of how to live sustainably, at individual or community decision-making levels. With increasing urban SETS complexity<sup>33,54</sup> comes an increased complexity of governance. Cities require multiple city agencies to deal with waste, park management, public health, crime, transportation, infrastructure, and

more. As the number of departments or agencies multiply, including ascendent sustainability and resilience departments, coordinating responses to build resilience and transform complex urban SETS along sustainability pathways faces institutional challenges of trade-offs between decisions still made in governance siloes<sup>11</sup>.

### URBANIZATION FOR THE ANTHROPOCENE

Building on the tradition of seeing the city and nature as interconnected, we argue for a response to the processes of urbanization that highlights the potential of both cities and their rural support areas as positive forces for sustainable development and governance.

Global sustainability will hinge on reshaping the nature of urbanization to bring it in balance with fundamental planetary limits and boundaries. We need a transformation of urbanization processes for a desired or “good” Anthropocene<sup>11,38,55–57</sup>.

1. Rescaling diversity—Diversity needs to match scales with emerging disturbance regimes to provide improved flexibility to respond to slow and fast local and global changes. Much of the diversity in and across urban areas is more or less intentionally designed and managed. Generating and acting on clear targets of desired diversity at different scales would be a first step towards building more options into how cities tackle regional sustainability challenges as well as prepare for and respond to emerging and even novel disturbance regimes and extreme events. Attention to and investment in diversity could include such strategies as 1) accelerating present trends of local and regional sourcing of more diverse foods, 2) intentionally designing hybrid green, blue, and gray infrastructure particularly with emphasis on diversity and flexibility, which may reduce vulnerability to disturbances<sup>58–60</sup>, 3) providing accessibility to regional and local multifunctional open space when mobility is reduced, for example during a pandemic<sup>61</sup>. In social contexts, diversity can be promoted by approaches such as co-management of urban commons<sup>48</sup>, and mobilizing different types of knowledge, which in turn can allow for multiple alternative opportunities for learning about and using the system. Plurality of institutional arrangements for managing different functions through processes of co-creation in parallel to streamlined planning processes may enable experimentation and simultaneous evaluation of multiple solutions to address challenges across urban regions<sup>15</sup>.
2. The anatomy of urbanization—managing connectivity and modularity—As discussed earlier, cross-scale linkages allow people to benefit from and draw on diversity external to their everyday environment. Linkages also allow disturbances to spread. Both reactive and proactive responses to change balance and actively work with connectivity and modularity for different aspects of the system (e.g., information vs. trade in goods or food) and in different situations and transformation towards more desirable and resilient ends. While a rich array of regional level studies of urbanization exist<sup>24</sup>, much of our knowledge about cities in the Anthropocene is either at a very high aggregate level, a global “urban”, or at the individual city level. These two perspectives need to be complemented by an intermediate level that explicitly addresses interlinkages and exchange. Cities are embedded in clusters of reciprocally interacting urban–rural multi-dimensional complexes characterized by different patterns, processes, and connections. Unpacking these complex relationships, accelerated by the exponential pace of urban change over the last few decades, can help us identify openings and opportunities for innovations in management of connectivity and modularity. Changes in

technology and shifting norms and values alter urbanization trajectories but at the same time could present opportunities to shift those trajectories toward local, regional, and global sustainability.

One example that could help steer urbanization pathways toward such positive trajectories is the initiation of new incentives for more sustainable landscape management that fosters new types of urban–rural connections, and also fosters city–city linkages focused on sustainability at larger scales. The flows and exchange that have been one of the characteristics of globalization are often seen as static, or difficult to change. However, the current COVID-19 pandemic has shown that these flows and exchanges can undergo fundamental change quite rapidly. For example, mobility has been curtailed by the COVID-19 lock-downs and overall restrictions on traveling, giving cities an incentive to rethink their approach towards urban space and suggest alternative options, as has occurred in cities across the world<sup>62</sup>. In many cities, systems for mobility are complemented by an emphasis on accessibility and modular design of the urban landscape to increase provision of essential services at a neighborhood scale. Managing globalization towards temporarily variable and more easily adjustable levels of modularity and connectivity across scale and within different subsystems (Fig. 1b) could provide an important new target for expanded urban resilience building.

3. Managing increasingly complex connections to the biosphere—Diversity, not least in the sense of increased specialization and longer functional chains with more interactions can also make functions more vulnerable, especially if it makes the linkages more opaque. On the other hand, functional diversity also allows for greater response diversity to deal with malign and unwanted change and disturbance that in turn nurtures resilience<sup>63</sup>. New crises will need complex responses where different actors/units can add complementary contributions, but this requires communication among actors, social trust, and ability to coordinate complexity.

If fundamental transformations are what we need to move towards sustainability<sup>11</sup> we need to understand what the different pathways would mean. For example, the COVID-19 crisis has provided multiple examples of indirect, far-reaching effects of seemingly targeted decisions. In response to these open-ended outcomes, many cities have been collaborating with a wide range of actors, including the national and regional governments, and urban stakeholders and citizens. These collaborations have enabled design and implementation of immediate, short-term and long-term responses to the multiple dimensions of the pandemic, and international city networks have played a key role in peer learning, exchanging knowledge, experience, medical equipment and protective gears, and in taking leadership in policy making<sup>49,62</sup>. Even though the pandemic has had extremely severe economic, social, and health effects across the globe, there are also positive outcomes, e.g., in its Adaptation Plan 2020, Milan is using the crisis to question fundamental characteristics and expectations of the city and its scale, creating new visions for increased wellbeing<sup>62</sup>.

The future process of urbanization in the post-COVID-19 Anthropocene where globalization processes may be more wisely managed and consequences of different decisions are easier to anticipate and plan for, would likely be strikingly different and take on a new face. Although urbanization may look different post-COVID-19, jobs, infrastructure, and opportunities will still for the foreseeable future exist and mainly expand in urban areas—of all sizes, including suburbs and peri-urban areas. We expect a multipolar world to develop though, where thriving local and

regional social, cultural, and ecological diversity and governance towards sustainability become more central, and a new urban–rural regional integration is possible. Global agendas such as the Sustainable Development Goals and the New Urban Agenda, provide a common roadmap and vision to engage local stakeholders, including the private sector and civil society in co-creating and building new urban visions and purposes. The three urbanization dimensions, as proposed in this paper, offer a framework for a potentially more successful realization of diverse positive urban visions and for guiding action towards a more regenerative urbanization in and for the Anthropocene.

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## AUTHOR CONTRIBUTIONS

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## COMPETING INTERESTS

The authors declare no competing interests.

## ADDITIONAL INFORMATION

**Correspondence** and requests for materials should be addressed to T.E.

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