Urban Transformations

PERSPECTIVE Open Access

Perspectives on urban transformation research: transformations *in*, *of*, and *by* cities

Katharina Hölscher[1*] and Niki Frantzeskaki[2]

* Correspondence: holscher@drift.eur.nl
[1]Dutch Research Institute for Transitions (DRIFT), Mandeville building (16th floor), Erasmus University Rotterdam, Burgemeester Oudlaan 50, 3062, PA, Rotterdam, The Netherlands
Full list of author information is available at the end of the article

Abstract

The narrative of 'urban transformations' epitomises the hope that cities provide rich opportunities for contributing to local and global sustainability and resilience. Urban transformation research is developing a rich yet consistent research agenda, offering opportunities for integrating multiple perspectives and disciplines concerned with radical change towards desirable urban systems. We outline three perspectives on urban transformations *in*, *of* and *by* cities as a structuring approach for integrating knowledge about urban transformations. We illustrate how each perspective helps detangle different questions about urban transformations while also raising awareness about their limitations. Each perspective brings distinct insights about urban transformations to ultimately support research and practice on transformations *for* sustainability and resilience. Future research should endeavour to bridge across the three perspectives to address their respective limitations.

Keywords: Cities, Urban transformations, Sustainability transitions, Resilience, Transformation research, Urban

Science highlights

- We outline three perspectives on urban transformations for explaining, structuring and integrating the emerging urban transformations research field.
- Transformation *in* cities focuses on unravelling the diverse factors, processes and dynamics driving place-based transformations in cities. This perspective represents research that aims to examine and explain why transformations occur and are supported in some places and not others.
- Transformation *of* cities examines the outcomes of transformative changes in urban (sub-)systems. It serves to understand and evaluate the emergence of new urban functions, new interactions and their implications for sustainability and resilience.
- Transformation *by* cities looks at the changes taking place on global and regional levels as a result of urbanisation and urban development approaches. The

perspective emphasises the agency of cities on a global scale and how transformation concepts travel between places.
- Future research should aim to bridge across the perspectives to address their respective limitations, for example by bringing in place-based knowledge ('in') into global discussions ('by') to facilitate cross-city learning.

Policy and practice recommendations

- Experimental, collaborative and place-based governance approaches facilitate the integration of local knowledge, the development of inspiring narratives that boost sense of place and empower local communities to boost transformations in cities.
- To assess and coordinate urban transformations, transformations, policy and practice actors need to employ systemic concepts and visions that advance solutions with multiple benefits for synergies and minimal trade-offs.
- Multi-level partnerships and (transnational) networks for policy knowledge exchange between cities help mobilising the potential of cities as agents of change for sustainability at a global scale.

Introduction

The notion of 'urban transformation' has been gaining ground in science and policy debates. Urban transformations to sustainability and resilience are enshrined in the 2030 United Nations Sustainable Development Goals (SDGs) (UN 2016) and the New Urban Agenda (UN-Habitat 2016a). A rich research field around questions of urban transformations has started to emerge, combining multiple scientific disciplines, ontologies and methods (Elmqvist et al. 2018, 2019; Wolfram et al. 2017; Vojnovic 2014). Key to these debates is the aim to put cities on a central stage for accelerating change towards local and global sustainability and resilience.

Urban transformation narratives have been driven by the recognition of the need and opportunity for radical change towards sustainable and resilient cities. Cities constantly experience changes, but contemporary urban change processes are unparalleled. Cities grapple with a variety of interrelated challenges, including pollution, poverty and inequality, ageing infrastructure and climate change (Haase et al. 2018; UN-Habitat 2016b; Seto et al. 2017). Urbanisation in its current form causes significant changes in land use, energy demand, biodiversity and lifestyles and raises questions about the contribution of cities to global environmental change (Haase et al. 2018; Alberti et al. 2018; Elmqvist et al. 2013; Seto et al. 2017). At the same time, cities concentrate the conditions and resources for realising the fundamental changes in energy, transportation, water use, land use, housing, consumption and lifestyles that are needed to ensure liveability, wellbeing and sustainability of our (urban) future (Romero-Lankao et al. 2018; Koch et al. 2016; Elmqvist et al. 2018). The potential and momentum in cities is visible in for example the 'climate emergency' declarations of local governments that call for accelerated climate action in view of international stalemate.

The notion of urban transformation guides and formulates a better understanding of urban change. On the one hand, 'transformation' serves as an analytical lens to describe and understand the continuous, complex and contested processes and dynamics manifesting in cities, as well as how these dynamics alter urban functions, local needs and

interactions between cities and their surroundings (McCormick et al. 2013; Iwaniec et al. 2019). On the other hand, the transformation perspective provides a normative orientation that emphasises the need for radical and systemic change in order to overcome persistent social, environmental and economic problems and to purposefully move towards sustainable and resilient cities in the long-term (Hölscher et al. 2019; Kabisch et al. 2018). Accordingly, sustainability and resilience are complementary concepts to asses and orient urban transformation processes (Elmqvist et al. 2019; Pickett et al. 2014; Simon et al. 2018).

In this paper, we distinguish three perspectives on urban transformations to structure and guide research and practice on urban transformations. Urban transformation research is an emergent, loosely connected interdisciplinary field combining urban studies and complex system studies. Various research fields and disciplines converge in urban transformation research; the multitude of disciplines has been systematically reviewed in Wolfram et al. (2017) and Wolfram and Frantzeskaki (2016). This diversity engenders multiple entry points and provides complementary concepts, theories and insights. However, the diversity causes ambiguities in ontologies, use of concepts and fragmented knowledge about how urban transformations unfold and can be supported.

Urban transformation research would benefit from "gradual interconnection, and the articulation of a certain range of research perspectives" (Wolfram and Frantzeskaki 2016: 2). To facilitate this, we distinguish and describe three perspectives on urban transformations that provide areas of convergence across diverse research approaches. Each perspective provides distinct starting points to generate, structure and integrate knowledge along certain questions. Ultimately, the perspectives outline an agenda for advancing theory and practice on urban transformations *for* sustainability and resilience: they generate implications for urban policy and practice and a way forward to bridge across the perspectives to address the respective limitations.

Perspectives on transformations in, of and by cities

We distinguish between perspectives on urban transformations *in*, *of* and *by* cities. The perspectives provide entry points for formulating and structuring research questions on urban transformations, integrating research approaches and knowledge, and deriving implications for practice.

The three perspectives start from similar assumptions about cities and urban transformations. They focus on urban transformations as complex processes of radical, systemic change across multiple dimensions (e.g. social, institutional, cultural, political, economic, technological, ecological) (Hölscher et al. 2018; Frantzeskaki et al. 2018a; McCormick et al. 2013). Cities are understood as complex, adaptive and open systems (Alberti et al. 2018; McPhearson and Wijsman, 2017; Ernstson et al., 2010; Collier et al. 2013). This implies that urban transformations are not spatially limited, and driven by and driving cross-scale and cross-sectoral dynamics: cities are "local nodes within multiple overlapping social, economic, ecological, political and physical networks, continuously shaping and shaped by flows of people, matter and information across scales" (Wolfram and Frantzeskaki 2016: 143; see also Hansen and Coenen 2015; Chelleri et al. 2015). To describe, explain and evaluate urban transformations, cities are increasingly approached as social-ecological-technical systems (SETS), including (1) socio-

economic, political and institutional dimensions (social); (2) natural resource flows and physical phenomena (ecological); (3) as well as the manmade surroundings (technological) (McPhearson 2020; Alberti et al. 2018; Bai et al. 2017). Actors have a central position within urban systems, influencing how cities are organised and resources are produced and consumed. Given the open character of urban systems, actors are diverse and include household members, local governments, and entrepreneurs also regional and national governments, international bodies and multinational companies, amongst others (Glaas et al. 2019; Webb et al. 2018).

Urban transformations can be desirable or undesirable (Elmqvist et al. 2019; Hölscher 2019). A shared aim across urban transformation research perspectives and approaches is to generate actionable knowledge to intervene in urban transformation processes and support radical change towards sustainable and resilient urban systems (cf. Wittmayer and Hölscher 2017).

Despite these shared starting points and aims, the perspectives ask distinct questions about transformations vis-à-vis urban systems. They look at systemic change dynamics taking place in cities ("in"), the outcomes of systemic change of cities ("of"), or systemic change on global and regional levels driven by cities ("by"). These entry points and corresponding questions manifest in differences along key descriptors of urban transformations (cf. Hölscher et al. 2018). The differences are not contradictory: they generate complementary insights for understanding and supporting urban transformations given the different level of aggregation, analysis and understanding of system dynamics and points of intervention (Table 1).

The main aim of the perspectives is to facilitate structuring of urban transformation research along shared themes and questions. Specifically, in articulating these, we show the actionable knowledge generated through each perspective to support urban transformations *for* sustainability and resilience. We also show that the perspectives offer bridges across knowledge to strengthen research and practice.

Transformation in cities: cities as places of transformations

Transformation *in* cities focuses on unravelling the diverse, local, regional and global factors, processes and interactions that converge in cities as places of transformations, thus driving or constraining place-based transformations.

The perspective zooms in on cities as spaces and places. Cities are geolocated in an objective, abstracted point, i.e. space, which is for example demarcated by geographical and administrative boundaries. Cities as places are defined by the physical (i.e. urban form) and philosophical (i.e. imagination and representation) relationships between people and place (Roche, 2016; Knox 2005). Thus, cities as places are both "a centre of meaning and the external context of people's actions" (Knox 2005: 2). As spaces and places of transformations, cities harbour specific potentials, driving forces and barriers (Hansen and Coenen 2015).

Place-based transformations are the result of the social construction by people responding to the opportunities and constraints of their particular locality (Fratini and Jensen 2017; Späth and Rohracher 2014). Endogenous conditions and developments include geographic location, climate, local economic structure, population dynamics and

Table 1 Perspectives on urban transformations

Descriptor of urban transformation	Transformation *in* cities	Transformation *of* cities	Transformation *by* cities
Key overarching questions guiding research and knowledge translation to policy and practice	How do urban transformations unfold, and how can urban transformations be supported towards sustainable and resilient urban systems?		
	Which factors, processes and dynamics drive place-based transformations in cities? Why do transformations occur and are supported in a specific context?	How do transformations affect urban (sub-)systems? What are synergies, trade-offs, vulnerabilities and thresholds?	How do change dynamics in cities impact their hinterland and other distant territories? How do transformations travel between places and across scales?
System focus	Cities are complex, adaptive and open social-ecological-technological systems (SETS)		
	Focus on cities as spaces and places of transformations that are geolocated and socially constructed, heterogeneous, multi-regime entities	Focus on functional urban (sub-)systems (e.g. economy, energy, transport, food, healthcare, housing) as the foci or the cogs of transformative changes	Focus on cities as agents of change due to being open systems and networks of global resource flows, commodities, communication and governance
System dynamics	Multi-dimensional, cross-sectoral and cross-scale factors and dynamics drive urban transformations, causing risk, uncertainty, inertia, break-down and innovation		
	Focus on (social construction of) local and translocal driving forces and barriers of place-based urban transformations	Focus on outcomes of system dynamics in urban (sub-)systems, including synergies, trade-offs, vulnerabilities and thresholds	Focus on dynamics and outcomes between cities and their hinterland or other distant territories (e.g. teleconnections, urban ecological footprint)
Agency and governance	Urban transformations are multi-actor, contested processes. Urban governance targets cities as geographical and administrative entities, but is embedded within multi-level governance structures and networks.		
	Transformative capacity of urban actors to develop and scale innovations Experimental, place-based governance approaches (e.g. living labs)	Orchestration of multi-actor activities and cross-sectoral and cross-scale partnerships	Polycentric and multilevel governance approaches, including transnational city networks

the built environment. For example, urban segregation and inequality result from and are reinforced by interactions between residential choices, personal preferences, job markets, land and real estate markets and public policies (Alberti et al. 2018). The construction of place-based transformations does not take place independently of societal norms and representations of the world. Economic and cultural globalisation and the resulting 'network society' becomes manifest in cities and shape place-based transformation dynamics (Roche, 2016). Scholars seeking to understand the 'geography in transitions' emphasise that cities are positioned within cross-scale spatial and institutional contexts that influence local change dynamics (Hansen and Coenen 2015; Truffer et al. 2015; Coenen et al. 2012; Hodson et al. 2017; McLean et al. 2016). Along similar lines, Loorbach et al. (2020) show the translocal character of social innovations that are locally rooted but globally connected.

This perspective positions transformative agency as deeply embedded in socio-spatial contexts. A central research focus is on urban niches that experiment with and scale

new solutions (McLean et al. 2016; Ehnert et al. 2018), governance arrangements (Wolfram 2019; Hölscher et al. 2019a) and ways of relating and knowing (Frantzeskaki and Rok 2018). Urban experimentation or real-world laboratories have become process tools to facilitate co-creative and innovative solution finding processes that empower actors to deal with urban problems, for example related to mobility, regeneration, community resilience or green job creation (Bulkeley et al. 2019; von Wirth et al. 2019; Hölscher et al. 2019c). Such approaches represent situated manners of place-making to co-develop inspiring 'narratives of place', empower local communities and foster urban transformative capacities (Wolfram 2019; Jensen et al. 2016; Ziervogel, 2019; Castán Broto et al. 2019). The idea of place-specificity recognises the particular role of 'sense of place' and 'place attachment', which can be an outcome of experimentation and in turn drive transformative change (Frantzeskaki et al., 2016; di Masso et al. 2019; Brink and Wamsler 2019). Ryan (2013) describes how multiple small 'eco-acupuncture' interventions can shift the community's ideas of what is permissible, desirable and possible.

A key value of this perspective lies on its embedded research inquiry into the 'black box' of a city, including social, economic and ecological situated and contextual knowledge. A main implication for urban policy and planning practice is to facilitate place-based innovation by going beyond sectoral infrastructuring and top-down masterplanning towards situated and cross-sectoral place-making. Experimental and co-creative governance approaches help recognise and mobilise place-specific capacities. The need for place-based innovation further calls for higher-level policies to be centred on the local dimension. For example, the current European Union Cohesion Policy puts a place-based approach into practice that recognises place variety (Solly 2016) and further extends it to a governance capacity building programme that engages with cities on the ground through the URBACT program (www.urbact.eu).

A limitation of this perspective is that knowledge about and actions instigating transformations in a specific city context are very entrenched in context dynamics. This can limit transferability or scaling other than 'scaling deep' pathway (Moore et al. 2015; Lam et al. 2020) if not connected with mechanisms for global and transnational learning and knowledge transfer (Section 2.3). In (Moore et al. 2015; Lam et al. 2020) addition, neighbourhood-level interventions need to be connected to knowledge about city-level outcomes. This calls for critical evaluations of systemic outcomes in urban systems (Section 2.2).

Transformation of cities: outcomes of transformation dynamics in urban systems

Transformation *of* cities examines and evaluates the outcomes of transformation dynamics in urban (sub-)systems in terms of new urban functions, local needs and interactions and implications for sustainability and resilience.

This perspective focuses on urban (sub-)systems defined by specific functions (e.g. economy, energy, transport, food, healthcare, housing). Compared to the other perspectives, it most explicitly applies socio-technical and social-ecological, and increasingly SETS, frameworks to describe urban (sub-)systems. Urban transformations are the outcome of radical changes of dominant structures (e.g. infrastructures, regulations), cultures (e.g. values) and practices (e.g. mobility behaviours) of such urban (sub-)systems.

As a result of these changes, what kind of and how system functions are delivered is fundamentally altered (Ernst et al. 2016).

The main aim of this perspective is to explain and evaluate how transformation dynamics affect urban systems' functions. Frameworks and models to investigate how transformation dynamics influence urban (sub-)systems pay attention to the complex processes and feedback loops within, across and beyond urban systems and the accumulated effects on the urban system level. For example, studying social-ecological-technical infrastructure systems in cities advances understanding of urban structure-function relationships between green space availability, wellbeing, biodiversity and climate adaptation (McPhearson 2020). Similarly, urban metabolism analysis and ecosystem studies seek to understand energy and material flows (Bai 2016; Dalla Fontana and Boas 2019). An emerging perspective on cities as 'multi-regime' configurations investigates dynamics across different functional systems (e.g. energy, water, mobility, food) (Grin et al. 2017; Irvine and Bai 2019). This provides opportunities to unveil interactions across multiple urban systems and scales. For instance, rapid changes in electricity systems can have knock-on effects for urban mobility or heat systems (Chen and Chen 2016; Chelleri et al. 2015). The relational geography perspective puts forth a differentiated view of urban systems: it zooms in on different boroughs, districts or neighbourhoods and raises questions such as how innovation and change in one location affects neighbouring locations (Wachsmuth et al. 2016).

This perspective most explicitly addresses prescriptive, 'goal'-driven and recently mission-driven orientations for reinventing cities to be more sustainable, resilient, inclusive, attractive, prosperous, safe and environmentally healthy (Elmqvist et al. 2018; Kabisch et al. 2018; Rudd et al. 2018). Researchers and urban practitioners and planners employ concepts like 'sustainability' and 'resilience' as frames to evaluate the state of urban systems and to inform urban planning and regeneration programmes (Elmqvist et al. 2019). The systemic focus and application of such concepts also helps to identify synergies and trade-offs across urban systems and goals. For example, the sustainability paradigm of maximising efficiency in mobility or energy systems might result in vulnerability to natural disasters when systems lack parallel or redundant back-up systems (ibid.). Similarly, scholars point to the risks of green gentrification: while urban greening interventions have multiple benefits for the environment and climate adaptation, if not planned and governed inclusively, they can create unintended dynamics of exclusion, polarisation and segregation (Anguelovski et al. 2019; Haase et al. 2017).

This perspective takes a meta-level view on the agency and governance in cities, highlighting strategic partnerships and interventions based on desired system-level outcomes. From this perspective, cities may act as coherent strategic entities based on systemic understandings of city-specific and long-term effects to pursue managed transitions of their large-scale (sub-)systems (Jensen et al. 2016; Hodson et al., 2017). Urban transformation governance needs to facilitate alignment, foresight and reflexive learning to recognise, anticipate and shape transformation dynamics and leverage points (Hölscher et al. 2019b). Key starting points are shared definitions of what 'desirability' means in specific contexts. Orchestration can align priorities and connect emerging alternatives, ideas, people and solutions (ibid.; Hodson et al., 2017). Shared and long-term visions re-orient short-term decisions and interventions that create synergies across multiple priorities. For example, Galvin and Maassen (2020) analyse Medellín's

(Columbia) mobility transformation that also contributed to inclusiveness and public safety. Transition management is a practice-oriented framework to co-develop shared visions, pathways and experiments in an ongoing learning-by-doing and doing-by-learning way (Frantzeskaki et al. 2018b; Loorbach et al. 2015).

In summary, this perspective provides a view on interpreting transformation dynamics and developing orientations and practical guidance for intervention. It becomes visible in urban planning and policy practice through the development of systemic urban concepts as 'anchor points' or attractors for urban transformations such as 'sharing cities', 'circular cities', or 'renaturing cities'. Cities like Rotterdam in the Netherlands and New York City in the USA are using such concepts to formulate long-term climate, sustainability and resilience agendas and establish cross-cutting city-level partnerships for their implementation (Hölscher et al. 2019a). A main implication of this perspective is about the need to institutionalise and prioritise such long-term agendas into policy and planning across sectors and scales (ibid.).

A limitation of this perspective is that it overlooks place-specific implications and can nuance or be agnostic to politics and contestations at local sub-system level. Strategically linking place-based initiatives (Section 2.1) with systemic urban concepts and visions provides a powerful tool to align the multitude of activities taking place in cities and to coordinate urban transformations on (sub-)system scale. Additionally, this perspective requires explicit attention to the relationships between urban systems and their hinterlands or other distant territories, which affect and are affected by urban system's functioning (Section 2.3).

Transformation by cities: cities as agents of change at global scale

The third perspective on transformation *by* cities draws attention to the changes taking place on global and regional levels as a result of urbanisation and urban development.

The main emphasis is here placed on cities as "agents of change at global scale" (Acuto 2016). As open systems, cities are not just influenced by developments outside their spatial boundaries (see Section 2.1). Urban transformations also have implications on global resources, environmental conditions, commodities and governance.

On the one hand, cities – including their social-ecological-technological configurations and the diversity of actors influencing them – can be viewed as culprits driving global high emissions, resource depletion and unsustainability. This raises critical questions about the relationship between current and unprecedented urbanisation and global sustainability (Seto et al. 2017; Haase et al. 2018). For example, the expansion of cities will triple land cover by 2030, compared to 2000, with severe implications on biodiversity (Alberti et al. 2018; Elmqvist et al. 2013). Different frameworks and concepts are employed to describe and assess the linkages between cities and their hinterland and other distant territories, including 'urban land teleconnections' (Seto et al. 2012), 'regenerative cities' (Girardet 2016) and 'urban ecological footprint' (Folke et al. 1997; Hoornweg et al. 2016; Rees and Wackernagel 2008).

On the other hand, cities have become key loci for trialling sustainable approaches and solutions that inform the global sustainability agenda (UN-Habitat 2016b; Seto et al. 2017; Bai et al. 2018). Cities – especially local governments – play key roles in shaping global sustainability programmes and discourses and in developing and sharing

knowledge and best practices. Local governments have also become celebrated for taking action when the national government is not (van der Heijden 2018; Acuto 2016). Governance strategies such as experimentation, best practices or imaginaries have been taken up globally (Haarstad 2016; McCann 2011; van der Heijden 2016). This raises questions about how the experiences and best practices showcased in cities become knowledge to be diffused and shared, as well as how transformations travel between places and across scales (Lam et al. 2020).

This perspective supports a polycentric and multi-level approach to global environmental governance. Global environmental governance is becoming increasingly decentralised and polycentric, which is visible for example in climate governance (Ostrom 2014; Jordan et al. 2018; Hölscher and Frantzeskaki 2020) and the urban SDG (UN 2016). The recent 'city charters' of global organisations such as the IPCC Cities and Climate Change, the Convention on Biological Diversity and Cities and Future Earth Urban Knowledge Network, showcase the recognition of 'cities' as key players on a global level. While urban sustainability governance has often proliferated without leadership at national levels, the nestedness of local governance in legal and institutional frameworks at regional, national and international levels requires alignment of priorities and legislation across governance levels (Hughes et al. 2017; Keskitalo et al. 2016).

In summary, this perspective creates knowledge about the role of cities in contributing to global change and what it means for governance, policy and planning at global, national, metropolitan and regional levels. It provides and requires big data from cities and their resource footprints, flows and dynamics so as to draw on patterns and pathways for change that can inform and reinforce global agendas for action. A key mechanism for urban practitioners is to strengthen policy knowledge exchange across frontrunning cities (Hölscher et al. 2019a). Transnational city networks such as the International Council for Local Environmental Initiatives (ICLEI), C40 and 100 Resilient Cities facilitate knowledge exchange and inter-city learning, foster the creation of collective goals, lobby for international attention, and enable the transplantation of innovative, sustainable and resilient policy and planning approaches (Acuto et al. 2017; Lee 2018; Mejía-Dugand et al. 2016; Frantzeskaki et al. 2019; Davidson et al. 2019).

A danger of this perspective is that this global discourse is mainly focused on 'global cities'. Medium-sized and middle-income cities are leaders in terms of actual sustainability performance and need to be actively acknowledged and considered (Vojnovic 2014). Florida (2017) criticises how "winner-take-all cities" reinforce inequality, while many cities stagnate and middle-class neighbourhoods disappear. This requires more research into how resources and opportunities are distributed and made accessible across different cities, for example 'global' cities, metropolitan cities and developing countries' cities (Coenen et al. 2012; Gavin et al. 2013). Additionally, cities are not necessarily a united front: priorities and interpretations differ across cities (Growe and Freytag 2019). To address these issues, this perspective would benefit from a more critical and contextual research approach on place-based transformations (Section 2.1), questioning why transformations occur and are supported in some places and not others. Comparative analyses into the factors and dynamics influencing place-based transformations can facilitate transnational knowledge transfer and upscaling of place-based initiatives.

Conclusions

We offer three perspectives on urban transformations research as a means to cherish and celebrate, but also structure the diversity of the growing urban transformations research field. Our paper is a first attempt to distinguish these perspectives, by discussing key questions, entry points, practical implications and limitations. We show that the perspectives help converge research approaches and clarify how different perspectives provide evidence for urban policy and planning.

The perspectives are not merely conceptual devices: they show up in cities' agendas, programmes and approaches and give guidance to practitioners. The 'transformation in cities' perspective asks practitioners to experiment with collaborative place-making approaches like urban living labs to integrate local knowledge and strengthen a sense of place and empowerment. The 'transformation of cities' perspective appears as underlying integrative systems' approach for core urban strategies such as climate change and biodiversity strategies. The 'transformation by cities' perspective highlights the need to invest in policy knowledge exchange between cities, for example through transnational city networks.

The three perspectives on urban transformation do not exist in isolation from one another. We have shown how the perspectives can feed into and complement each other to address respective research gaps and practical challenges. The main future research direction we put forth is to bridge across the perspectives to address their respective limitations and generate comprehensive actionable knowledge. This means to formulate integrative research questions bridging across perspectives: How do place-making initiatives in a specific neighbourhood affect urban systems' functioning? How can place-based transformation knowledge be transferred to other city contexts? How can place-based experiments and transformation initiatives or projects inform policy at city and city-network level? What are the conditions for downscaling strategic initiatives from global level – for example, post-Aichi biodiversity targets – considering capacities of urban sub-systems?

Abbreviations

HUD: US Department of Housing and Urban Development; ICLEI: International Council for Local Environmental Initiatives; IPCC: International Panel on Climate Change; SDG: Sustainable Development Goal; SETS: Social-ecological-technological system; UN: United NationsMeerow, S

Acknowledgements

Not applicable.

Ethical approval and consent to participate

Not applicable.

Authors' contributions

KH conceived of the conceptual structuring approach. Both authors contributed equally to the literature review and drafted the manuscript. All authors read and approved the final manuscript.

Funding

The research leading to this article has received funding from the European Community's Framework Program Horizon 2020 for the Connecting Nature Project (grant agreement no. 730222; www.connectingnature.eu) and the European Community's Framework Program FP7 for the IMPRESSIONS project [grant number 603416, www.impressions-project.eu].

Availability of data and materials

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Consent for publication

Not applicable.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Dutch Research Institute for Transitions (DRIFT), Mandeville building (16th floor), Erasmus University Rotterdam, Burgemeester Oudlaan 50, 3062, PA, Rotterdam, The Netherlands. [2]Centre for Urban Transitions, Level 1 EW Building, Swinburne University of Technology, Hawthorn, VIC 3122, Australia.

Received: 24 October 2019 Accepted: 20 January 2021
Published online: 12 February 2021

References

Acuto M. Give cities a seat at the top table. Nature. 2016;537:611–3.
Acuto M, Morissettte M, Tsouros A. City diplomacy: towards more strategic networking? Learning with WHO health cities. Global Policy. 2017;8(1):14–22. https://doi.org/10.1111/1758-5899.12382.
Alberti M, McPhearson T, Gonzalez A. Embracing urban complexity. In: Elmqvist T, Bai X, Frantzeskaki N, Griffith C, Maddox D, McPhearson T, Parnell S, Romero-Lankao P, Simon D, Watkins M, editors. Urban planet: knowledge towards sustainable cities. Cambridge: Cambridge University Press; 2018. p. 68–91.
Anguelovski I, Connolly JJT, Pearsall H, Shokry G, et al. Opinion: why green "climate gentrification" threatens poor and vulnerable populations. PNAS. 2019;116(52):26139–43. https://doi.org/10.1073/pnas.1920490117.
Bai X. Eight energy and material flow characteristics of urban ecosystems. Ambio. 2016;45(7):819–30. https://doi.org/10.1007/s13280-016-0785-6.
Bai X, Dawson RJ, Ürge-Vorsatz D, Delgado GC, Salisu Barau A, Dhakal S, Dodman D, Leonardsen L, Masson-Delmotte V, Roberts DC, Schultz S. Six research priorities for cities and climate change. Nature. 2018;555:23–5. https://doi.org/10.1038/d41586-018-02409-z.
Bai X, McPhearson T, Cleugh H, Nagendra H, Tong X, Zhu T, Zhu Y-G. Linking urbanization and the environment: conceptual and empirical advances. Annual review of environment and resources. 2017;42:215–40. https://doi.org/10.1146/annurev-environ-102016-061128.
Brink E, Wamsler C. Citizen engagement in climate adaptation surveyed: The role of values, worldviews, gender and place. J Clean Prod. 2019;209:1342–53. https://doi.org/10.1016/j.jclepro.2018.10.164.
Bulkeley H, Marvin S, Palgan YV, McCormick K, Breitfuss-Loidl M, Mai L, von Wirth T, Frantzeskaki N. Urban living laboratories: conducting the experimental city? Eur Urban Regional Stud. 2019;26(4). https://doi.org/10.1177/0969776418787222.
Castán Broto V, Trencher G, Iwaszuk E, Westman L. Transformative capacity and local action for urban sustainability. Ambio. 2019;48(5):449–62.
Chelleri L, Water JJ, Olazabal M, Minucci G. Resilience trade-offs: addressing multiple scales and temporal aspects of urban resilience. Environmet Urbanization. 2015;27(1):181–98. https://doi.org/10.1177/0956247814550780.
Chen S, Chen B. Urban energy-water nexus: a network perspective. Appl Energy. 2016;184:905–15. https://doi.org/10.1016/j.apenergy.2016.03.042.
Coenen L, Benneworth P, Truffer B. Toward a spatial perspective on sustainability transitions. Res Policy. 2012;41(6):968–79. https://doi.org/10.1016/j.respol.2012.02.014.
Collier MJ, Nedovic-Budic Z, Aerts J, Connop S, Foley D, Foley K, Newport D, McQuaid S, Slaev A, Verburg P. Transitioning to resilience and sustainability in urban communities. Cities. 2013;32:S21–8.
Dalla Fontana M, Boas I. The politics of the nexus in the city of Amsterdam, Cities; 2019. p. 95. https://doi.org/10.1016/j.cities.2019.102388.
Davidson K, Coenen L, Acuto M, Gleeson B. Reconfiguring urban governance in an age of rising city networks: a research agenda, urban studies; 2019. p. 1–16. https://doi.org/10.1177/0042098018816010.
Di Masso A, Williams DR, Raymond CM, et al. Between fixities and flows: navigating place attachments in an increasingly mobile world. J Environ Psychol. 2019;61:125–33. https://doi.org/10.1016/j.jenvp.2019.01.006.
Ehnert F, Frantzeskaki N, Barnes J, Borgström S, Gorissen L, Kern F, Strenchock F, Egermann M. The Acceleration of Urban Sustainability Transitions: a Comparison of Brighton, Budapest, Dresden, Genk, and Stockholm. Sustainability. 2018;10(3):612. https://doi.org/10.3390/su10030612.
Elmqvist T, Andersson E, Frantzeskaki N, McPhearson T, Olsson P, Gaffney O, Takeuchi K, Folke C. Sustainability and resilience for transformation in the urban century. Nature Sustainability. 2019;2:267–73. https://doi.org/10.1038/s41893-019-0250-1.
Elmqvist T, Bai X, Frantzeskaki N, Griffith C, Maddox D, McPhearson T, Parnell S, Romero-Lankao P, Simon D, Watkins M, editors. Urban planet: knowledge towards sustainable cities. Cambridge: Cambridge University Press; 2018.
Elmqvist T, Fragkias M, Goodness J, Guneralp B, Marcotullio PJ, McDonald RI, Parnell S, Schewenius M, Sendstad M, Seto KC, Wilkinson C. Urbanization, biodiversity and ecosystem services: challenges and opportunities. A global assessment Dordrecht: Springer; 2013. https://doi.org/10.1007/978-94-007-7088-1.
Ernst L, de Graaf-Van Dinther RE, Peek GJ, Loorbach D. Sustainable urban transformation and sustainability transitions; conceptual framework and case study. J Clean Prod. 2016;112:2988–99. https://doi.org/10.1016/j.jclepro.2015.10.136.
Ernstson H, van der Leeuw SE, Redman CL, et al. Urban transitions: on urban resilience and human-dominated ecosystems. AMBIO. 2010;39:531–45. https://doi.org/10.1007/s13280-010-0081-9.
Florida R. The new urban crisis: how our cities are increasing inequality, deepening segregation, and failing the middle class – and what we can do about it. New York: Basic Books; 2017.
Folke C, Jansson A, Larsson J, Costanza R. Ecosystem appropriation by cities. AMBIO. 1997;26(3):167–72.
Frantzeskaki N, Bach M, Hölscher K, Avelino F. Transition management in and for cities: introducing a new governance approach to address urban challenges. In: Frantzeskaki N, Hölscher K, Bach M, Avelino F, editors. co-creating sustainable urban futures. A primer on applying transition management in cities. Tokyo: Springer; 2018a.
Frantzeskaki N, Bach M, Mguni P. Understanding the urban context and its challenges. In: Frantzeskaki N, Hölscher K, Bach M, Avelino F, editors. Co-creating sustainable urban futures. A primer on applying transition management in cities. Tokyo: Springer; 2018b. p. 43–62.

Frantzeskaki N, Buchel S, Spork C, Ludwig K, Kok MTJ. The multiple roles of ICLEI: intermediating to innovate urban biodiversity governance. Ecol Econ. 2019;164:106350. https://doi.org/10.1016/j.ecolecon.2019.06.005.
Frantzeskaki N, Dumitru A, Anguelovski I, Avelino F, Bach M, Best B, Binder C, Barnes J, Carrus J, Egermann M, Haxeltine A, Moore ML, Mira RG, Loorbach D, Uzzell D, Omman I, Olsson P, Silvestri G, Stedman R, Wittmayer J, Durrant R, Rauschmayer F. Elucidating the changing roles of civil society in urban sustainability transitions. Curr Opin Environ Sustain. 2016;22:41–50.
Frantzeskaki N, Rok A. Co-producing urban sustainability transitions knowledge with community, policy and science. Environmental Innovation and Societal Transitions. 2018;29:47–51. https://doi.org/10.1016/j.eist.2018.08.001.
Fratini CF, Jensen JS. The Role of Place-specific Dynamics in the Destabilization of the Danish Water Regime: An Actor–Network View on Urban Sustainability Transitions. In: Frantzeskaki N, Castán Broto V, Loorbach D, Coenen L, editors. Urban sustainability transitions: Routledge; 2017.
Galvin M, Maassen A. Connecting formal and informal spaces: a long-term and multi-level view of Medellín's Metrocable. Urban Transformations. 2020;2(1).
Gavin B, Bouzarovski S, Bradshaw M, Eyre N. Geographies of energy transition: Space, place and the low-carbon economy. Energy Policy. 2013;53:331–40.
Girardet H. Regenerative cities. In: Shmelev S, editor. Green economy reader. Studies in ecological economics, vol 6. Cham: Springer; 2016. p. 183–204.
Glaas E, Hjerpe M, Storbjörk S, Neset TS, Bohman A, Muthumanickam P, Johansson J. Developing transformative capacity through systematic assessments and visualization of urban climate transitions. Ambio. 2019;48:515–28. https://doi.org/10.1007/s13280-018-1109-9.
Grin, J., Frantzeskaki, N., Castàn Broto, V., Coenen, L. (2017) Sustainability transitions and the cities: linking to transition studies and looking forward. In: Frantzeskaki, N., Castán Broto, V., Coenen, L., Loorbach, D. (eds.) Urban sustainability transitions. Routledge Studies in Sustainability Transitions: New York and London, pp. 359–367.
Growe A, Freytag T. Image and implementation of sustainable urban development: showcase projects and other projects in Freiburg, Heidelberg and Tübingen, Germany. Spatial Res Planning. 2019;77(5):457–74. https://doi.org/10.2478/rara-2019-0035.
Haarstad H. Where are urban energy transitions governed? Conceptualizing the complex governance arrangements for low-carbon mobility in Europe, Cities. 2016;54:4–10.
Haase D, Güneralp B, Dahiya B, Bai X, Elmqvist T. Global Urbanization. In: Elmqvist T, Bai X, Frantzeskaki N, Griffith C, Maddox D, McPhearson T, Parnell S, Romero-Lankao P, Simon D, Watkins M, editors. Urban planet: knowledge towards sustainable cities. Cambridge: Cambridge University Press; 2018. p. 19–44.
Haase D, Kabisch S, Haase A, Andersson E, Banzhaf E, Baro F, Brenck M, Fischer LK, Frantzeskaki N, Kabisch N, Krellenberg K, Kremer P, Kronenberg J, Larondelle N, Mathey J, Pauleit S, Ring I, Rink D, Schwarz N, Wolf M. Greening cities - to be socially inclusive? About the alleged paradox of society and ecology in cities, Habitat International. 2017;64:41–8. https://doi.org/10.1016/j.habitatint.2017.04.005.
Hansen T, Coenen L. The geography of sustainability transitions: review, synthesis and reflections on an emergent research field. Environmental Innovation and Societal Transitions. 2015;17:92–109. https://doi.org/10.1016/j.eist.2014.11.001.
Hodson M, Geels F, McMeekin A. Reconfiguring urban sustainability transitions, Analysing multiplicity. Sustainability. 2017;9(2):299–20.
Hölscher K. Transforming urban climate governance. Capacities for transformative climate governance. PhD thesis, Erasmus University Rotterdam; 2019.
Hölscher K, Frantzeskaki F, McPhearson T, Loorbach D. Tales of transforming cities: transformative climate governance capacities in New York City, U.S. and Rotterdam, Netherlands. J Environ Manag. 2019a;231:843–57. https://doi.org/10.1016/j.jenvman.2018.10.043.
Hölscher K, Frantzeskaki F, McPhearson T, Loorbach D. Capacities for urban transformations governance and the case of New York City. Cities. 2019b;94:186–99. https://doi.org/10.1016/j.cities.2019.05.037.
Hölscher K, Frantzeskaki N. A transformative perspective on climate change and climate governance. In: Hölscher K, Frantzeskaki N, editors. Transformative climate governance. A capacities perspective to systematise, evaluate and guide climate action: Palgrave Macmillan; 2020.
Hölscher K, Wittmayer JM, Avelino F, Giezen M. Opening up the transition arena: an analysis of (dis) empowerment of civil society actors in transition management in cities. Technol Forecast Soc Chang. 2019c;145:176–85. https://doi.org/10.1016/j.techfore.2017.05.004.
Hölscher K, Wittmayer JM, Loorbach D. Transition versus transformation: What's the difference? Environmental Innovation and Societal Transitions. 2018. https://doi.org/10.1016/j.eist.2017.10.007.
Hoornweg D, Hosseini M, Kennedy C, Behdadi A. An urban approach to planetary boundaries. Ambio. 2016;45:567–80. https://doi.org/10.1007/s13280-016-0764-y.
Hughes S, Chu EK, Mason SG, editors. Climate change in cities. Innovations in Multi-level Governance: Springer; 2017.
Irvine S, Bai X. Positive inertia and proactive influencing towards sustainability: systems analysis of a frontrunner city. Urban Transform. 2019;1:1. https://doi.org/10.1186/s42854-019-0001-7.
Iwaniec DM, Cook EM, Barbosa O, Grimm NB. The framing of urban sustainability transformations. Sustainability. 2019;11:573. https://doi.org/10.3390/su11030573.
Jensen JS, Fratini CF, Cashmore MA. Socio-technical systems as place-specific matters of concern: the role of urban governance in the transition of the wastewater system in Denmark. J Environmental Policy Planning. 2016;18(2):234–52. https://doi.org/10.1080/1523908X.2015.1074062.
Jordan A, Huitema D, van Asselt H, Forster J. Governing climate change: the promise and limits of polycentric governance. In: Jordan A, Huitema D, van Asselt H, Forster J, editors. Governing climate change. Polycentricity in action? Cambridge: Cambridge University press; 2018. p. 359–83.
Kabisch S, Koch F, Gawel E, Haase A, Knapp S, Krellenberg K, Zehnsdorf A. Introduction: Urban transformations – sustainable urban development through resource efficiency, quality of life, and resilience. In: Kabisch S, Koch F, Gawel E, Haase A, Knapp S, Krellenberg K, Nivala J, Zehnsdorf A, editors. Urban transformations - Sustainable urban development through resource efficiency, quality of life and resilience. Future City 10: Springer International Publishing; 2018. p. xvii–xxviii.

Keskitalo ECH, Juhola S, Baron N, Fyhn H, Klein J. Implementing local climate change adaptation and mitigation actions: the role of Varios policy instruments in a multi-level governance context. Climate. 2016;4(1):7. https://doi.org/10.3390/cli4010007.
Knox PL. Creating ordinary places: slow cities in a fast world. J Urban Des. 2005;10(1):1–11. https://doi.org/10.1080/13574800500062221.
Koch F, Krellenberg K, Kabisch S. (2016) How to achieve urban sustainability transformations (UST) in real life politics? Brief for GSDR – 2016 Update. https://sustainabledevelopment.un.org/content/documents/961514_Koch%20et%20al._How%20to%20achieve%20Urban%20Sustainability%20Transformations%20(UST)%20in%20real%20life%20politics.pdf. Accessed: 4 Oct 2018.
Lam DPM, Martín-López B, Wiek A, et al. Scaling the impact of sustainability initiatives: a typology of amplification processes. Urban Transform. 2020;2:3. https://doi.org/10.1186/s42854-020-00007-9.
Lee T. Network comparison of socialization, learning and collaboration in the C40 cities climate group. J Environmental Policy Planning. 2018. https://doi.org/10.1080/1523908X.2018.1433998.
Loorbach D, Frantzeskaki N, Huffenreuter LR. Transition management: taking stock from governance experimentation. J Corp Citizsh. 2015;58:48–66.
Loorbach D, Wittmayer JM, Avelino F, von Wirth T, Frantzeskaki N. Transformative innovation and translocal diffusion. Environmental Innovation and Societal Transitions. 2020. https://doi.org/10.1016/j.eist.2020.01.009.
McCann E. Urban policy mobilities and global circuits of knowledge: towards a research agenda. Ann Assoc Am Geogr. 2011;101(1):107–30.
McCormick K, Anderberg S, Coenen L, Neij L. Advancing sustainable urban transformation. J Clean Prod. 2013;50:1–11. https://doi.org/10.1016/j.jclepro.2013.01.003.
McLean A, Bulkeley H, Crang M. Negotiating the urban smart grid: socio-technical experimentation in the city of Austin. Urban Stud. 2016;53(15):3246–63. https://doi.org/10.1177/0042098015612984.
McPhearson T. Transforming cities and science for climate change resilience in the Anthropocene. In: Hölscher K, Frantzeskaki N, editors. Transformative climate governance. A capacities perspective to systematise, evaluate and guide climate action: Palgrave Macmillan; 2020.
McPhearson T, Wijsman K. Transitioning complex Urban Systems. The importance of urban ecology for sustainability in New York City. In: Frantzeskaki N, Castán Broto V, Coenen L, Loorbach D, editors. Urban sustainability transitions. Springer; 2017.
Mejía-Dugand S, Kanda W, Hjelm O. Analyzing international city networks for sustainability: a study of five major swedish cities. Journal of cleaner production, 134(part a): 61-69. 2016. https://doi.org/10.1016/j.jclepro.2015.09.093.
Moore ML, Riddell D, Vocisano D. Scaling out, scaling up, scaling deep: strategies of non-profits in advancing systemic social innovation. J Corporate Citizenship. 2015;58:67–85.
Ostrom E. A polycentric approach for coping with climate change. Ann Econ Financ. 2014;15:71–108. https://doi.org/10.1596/1813-9450-5095.
Pickett STA, McGrath B, Cadenasso ML, Felson AJ. Ecological resilience and resilient cities. Building ResInformation. 2014;42(2):143–57. https://doi.org/10.1080/09613218.2014.850600.
Rees W, Wackernagel M. Urban ecological footprints: why cities cannot be sustainable – and why they are key to sustainability. In: Marzluff JM, et al., editors. Urban ecology. Boston, MA: Springer; 2008. p. 537–55.
Roche S. Geographic information science II: less space, more places in smart cities. Prog Hum Geogr. 2016;40(4):565–73. https://doi.org/10.1177/0309132515586296.
Romero-Lankao P, Bulkeley H, Pelling M, Burch S, Gordon D, Gupta J, Johnson C, Kurian P, Simon D, Tozer L, Ziervogel G, Munshi D. Realizing urban transformative potential in a changing climate. Nat Clim Chang. 2018a. https://doi.org/10.1038/s41558-018-0264-0.
Rudd A, Simon D, Cardama M, Birch EL, Revi A. The UN, the urban sustainable development goal, and the new urban agenda. In: Elmqvist T, Bai X, Frantzeskaki N, Griffith C, Maddox D, McPhearson T, Parnell S, Romero-Lankao P, Simon D, Watkins M, editors. Urban planet: knowledge towards sustainable cities. Cambridge: Cambridge University Press; 2018. p. 180–96.
Ryan C. Eco-acupuncture: designing and facilitating pathways for urban transformation, for a resilient low-carbon future. J Clean Prod. 2013;50:189–99. https://doi.org/10.1016/j.jclepro.2012.11.029.
Seto KC, Golden JS, Alberti M, Turner BL II. Sustainability in an urbanizing planet. PNAS. 2017;114(34):8935–8.
Seto KS, Reenberg A, Boone CC, Fragkias M, Haase D, Langanke T, Marcotullio P, Munroe DK, Olah B, Simon D. Teleconnections and sustainability: new conceptualizations of global urbanization and land change. PNAS. 2012;109(20):7687–92. https://doi.org/10.1073/pnas.1117622109.
Simon D, Griffith C, Nagendra H. Rethinking urban sustainability and resilience. In: Elmqvist T, Bai X, Frantzeskaki N, Griffith C, Maddox D, McPhearson T, Parnell S, Romero-Lankao P, Simon D, Watkins M, editors. Urban planet: knowledge towards sustainable cities. Cambridge: Cambridge University Press; 2018. p. 149–62.
Solly A. Place-based innovation in cohesion policy: meeting and measuring the challenges. Reg Stud Reg Sci. 2016;3(1):193–8. https://doi.org/10.1080/21681376.2016.1150199.
Späth P, Rohracher H. The interplay of urban energy policy and socio-technical transitions: the eco-cities of Graz and Freiburg in retrospect. Urban Stud. 2014;51(7):1415–31. https://doi.org/10.1177/0042098013500360.
Truffer B, Murphy JT, Raven R. The geography of sustainability transitions: contours of an emerging theme. Environmental Innovation and Societal Transitions. 2015;17:63–72. https://doi.org/10.1016/j.eist.2015.07.004.
UN (2016) Transforming our world: the 2030 Agenda for sustainable development. A/Res/70/1. http://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf. Accessed: 4 Oct 2018.
UN-Habitat (2016a) New Urban Agenda. http://habitat3.org/wp-content/uploads/NUA-English.pdf
UN-Habitat. Urbanization and Development. Emerging Futures. World Cities Report 2016. Nairobi: UN-Habitat; 2016b.
Van der Heijden J. Experimental governance for low-carbon buildings and cities: value and limits of local action networks. Cities. 2016;53:1–7.
Van der Heijden J. City and subnational governance: high ambitions, innovative instruments and polycentric collaborations? In: Jordan A, Huitema D, van Asselt H, Forster J, editors. governing climate change. Polycentricity in action? Cambridge: Cambridge University press; 2018. p. 81–96.
Vojnovic I. Urban sustainability: research, politics, policy and practice. Cities. 2014;41:30–44.
Von Wirth T, Fuenfschilling L, Frantzeskaki N, Coenen L. Impacts of urban living labs on sustainability transitions: mechanisms and strategies for systemic change through experimentation. Eur Plan Stud. 2019;27(2):229–57.

Wachsmuth D, Cohen DA, Angelo H. Expand the frontiers of urban sustainability. Nature. 2016;536:391–3. https://doi.org/10.1038/536391a.
Webb R, Bai X, Smith MS, Costanza R, Griggs D, Moglia M, Neuman M, Newman P, Newton P, Norman B, Ryan C, Schandl H, Steffen W, Tapper N, Thomson G. sustainable urban systems: co-design and framing for transformation. Ambio. 2018;47:57–77. https://doi.org/10.1007/s13280-017-0934-6.
Wittmayer J, Hölscher K. Transformationsforschung – Definitionen, Ansätze, Methoden. Bericht des AP1. Dessau-Roßlau: Umweltbundesamt; 2017. https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2017-11-08_texte_103-2017_transformationsforschung.pdf
Wolfram M. Assessing transformative capacity for sustainable urban regeneration: a comparative study of three south Korean cities. Ambio. 2019. https://doi.org/10.1007/s13280-018-1111-2.
Wolfram M, Frantzeskaki N. Cities and systemic change for sustainability: prevailing epistemologies and an emerging research agenda. Sustainability. 2016;8:144. https://doi.org/10.3390/su8020144.
Wolfram M, Frantzeskaki N, Maschmeyer S. Cities, systems and sustainability: status and perspectives of research on urban transformations. Curr Opin Environ Sustain. 2017;22:18–25. https://doi.org/10.1016/j.cosust.2017.01.014.
Ziervogel G. Building transformative capacity for adaptation planning and implementation that works for the urban poor: insights from South Africa. Ambio. 2019;48:494–506. https://doi.org/10.1007/s13280-018-1141-9.

Publisher's Note