Commentary

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Towards resilient African cities: Shared challenges and opportunities towards the retention and maintenance of ecological infrastructure

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Non-technical summary

There are significant challenges to retaining indigenous biodiversity and ecological infrastructure in African cities. These include a lack of formal protection and status for remnant ecologically functional patches rendering them open to *ad hoc* human settlement, which is in part linked to weak governance and management emerging from complex histories, and competing crisis-ridden demands. Persistent gaps in knowledge and practice mean that the social, economic, development and well-being benefits of ecological infrastructure are not understood or demonstrated. Addressing these challenges requires the adoption of multiple top-down government interventions and bottom-up community and neighbourhood actions. The development of detailed case studies that engage with knowledge generation and sharing at multiple scales through co-learning practices will also help create a much-needed deeper understanding of development options within this context.

Technical summary

The retention and maintenance of ecological infrastructure is recognized as an important element of sustainable, healthy cities. We explore the shared challenges and opportunities linked to ensuring that ecological infrastructure is incorporated into the existing and emerging African cities that we work in. Identified challenges relate to emerging urban form and function where remnant ecologically functional patches that provide ecosystem services are insecure and open to transformation through *ad hoc* settlement. Weak governance and management emerging from complex histories and competing crisis-ridden demands mean that securing ecological infrastructure in cities tends to be overlooked. Persistent gaps in knowledge and practice result in the failure to demonstrate the social, economic, development and well-being benefits of ecological infrastructure. We believe that these can be attended to through the development of detailed case studies that engage with knowledge generation at multiple scales, the creation of substantial datasets and the mobilization of existing knowledge bases through novel information sharing and co-learning practices. Securing ecological infrastructure in African cities will require the subversion of institutions across disciplines and scales, with a high degree of local civic action. The African context provides new learning opportunities, helping to both understand the broader 'African' case and all cities and their future developments.

Social media summary

Resilient African cities need to retain ecological infrastructure through multiple small-scale, bottom-up interventions.

Introduction

Cities in Africa are growing faster than in any other region of the world (CBO, 2012; Seto *et al.*, 2011; UN-DESA, 2014). This rapid growth manifests in different ways across the continent. Each city has distinct characteristics and faces unique challenges; however, there are also a number of fundamental shared features of African cities (Anderson *et al.*, 2013). It is clear that cities emerging in this region are different from cities in the Global North (Guneralp *et al.*, 2017). Dominant shared features that make them distinct include poverty and undeveloped human capital (Boadi *et al.*, 2005), high population growth rates, informality (Pieterse, 2006, 2009, 2011), a heavy reliance on natural resources (Anderson *et al.*, 2013), persistent transhumance patterns that connect cities and rural landscapes (Anderson *et al.*, 2013) and rapidly expanding or sprawling city areas driving local and global environmental change (Parnell & Walawege, 2011), particularly around biodiversity hotspots (Guneralp *et al.*, 2017). Furthermore, the impacts of climate change, which are affecting Africa significantly faster than the rest of the world and to a greater degree, will further expose African cities to risk of natural disasters (Adelekan *et al.*, 2015).

Africa's urban population is expected to more than triple in 40 years, from 395 million in 2010 to 1.339 billion in 2050, corresponding to 21% of the world's projected urban population (Guneralp *et al.*, 2017). The physical footprints of African cities are predicted to grow by eightfold between 2000 and 2030, and most of the infrastructure associated with this expansion has yet to be built (Adesina *et al.*, 2016; Swilling, 2016). This implies that there is the potential to test and adopt alternative development pathways to those that we see in Global North city contexts, in which structural lock-in and problematic development issues could be avoided. Furthermore, African cities are dynamic and open to innovation, presenting a significant opportunity for researchers and development practitioners to influence and guide emerging urban forms that are both appropriate to the African context and ecologically resilient.

To manage these growing and dynamic urban systems we need to be able to account for this complexity. There are multiple useful conceptual models, frameworks and approaches that can assist us. Whilst acknowledging the debates (Meerow & Newell, 2019), resilience approaches or frameworks are well suited to enabling us to assess the current situation through identifying challenges and opportunities, and they have the potential to be catalytic in prompting and directing how we transform and develop in the short term. They typically and deliberately combine a range of considerations, such as the physical form of the environment and associated ecosystem processes and services, social and institutional issues, and they are flexible in that they are open to the inclusion of distinct and complementary conceptual constructs as required (Biggs *et al.*, 2015). We adopt an exploratory approach in looking at ecological infrastructure in a manner akin to that promoted in resilience studies. Conceptually, resilience provides us with the frameworks and language that can enable us to direct developments so that they retain a vital ecological infrastructure while meeting the needs of cities (Biggs *et al.*, 2015).

When using a resilience lens to consider development within African urban contexts, a foundational issue is the harmonization of the physical city growth and development with the ecology of the city (Cobbinah & Darkwah, 2016) that provides multiple invaluable ecosystem services to city residents (Gómez-Baggethun *et al.*, 2013; Guneralp *et al.*, 2017). Ecological infrastructure refers to naturally functioning ecosystems that deliver valuable services to people, such as filtered water and climate regulation, soil formation and disaster risk reduction (SANBI, 2014). These natural ecological infrastructure networks help meet infrastructure needs. Although there are a plethora of studies investigating sustainable urban infrastructure, most of this work has been undertaken in the Global North, with a dearth of work from Africa (Ferrer *et al.*, 2018; McHale *et al.*, 2013). Building cities while strategically retaining, benefiting from and, in some instances, restoring ecological infrastructure in a manner that is matched with or aligned to current and future social needs requires a detailed understanding of the shared challenges and opportunities associated with our urban ecological systems. Deeper understanding of these can direct us towards sustainable and resilient development pathways (Culwick *et al.*, 2016; McHale *et al.*, 2013).

This commentary emerged from a three-day workshop involving all of the authors who are researchers, practitioners and innovators working in African cities, focused on identifying the shared challenges and opportunities to the maintenance and retention of ecological infrastructure associated with African city contexts. Collectively, we have experience working in the cities of Addis Ababa, Cape Town, Dar es Salaam, Durban, Gaborone, Inhambane, Johannesburg, Kampala, Kisumu, Lilongwe, Lusaka, Maputo and Windhoek. We recognize and acknowledge differences across the continent and speak collectively in general terms as it is necessary here; however, we do so with caution. While individual cities differ, here we attempt to draw out the common African challenges and opportunities towards informing collective action, part of which is the augmentation of more detailed case study work that would both speak to macro-scale views and inform city-specific understandings. We see this as a key first step towards alternative development pathways that can ultimately build future resilience and ensure well-being in African cities. We believe this commentary may be of use to city managers, planners, funding agencies, investors and researchers, and it may facilitate the redesign of engagements, projects and research around our identified key challenges. In particular, we hope it will serve to bridge the divide between different disciplines as they relate to ecological infrastructure.

Challenges faced in the retention and maintenance of ecological infrastructure

Form and function

In many African cities, natural areas are highly utilized, unprotected and vulnerable to transformation. The degree of pressures on these natural resources and systems is largely unmeasured and undocumented. African cities frequently have a high proportion of intact nature, and their urban residents have a high degree of reliance on the natural resources found within these areas (Cilliers *et al.*, 2013). For example, in Lilongwe (Malawi), it was reported that almost 70% of community members rely on natural resources for their livelihoods (Allan Kwanjana, Director of the Parks, Recreation and Environment Directorate, Lilongwe City

Council, personal communication, 2016). They draw on these for a variety of provisioning services linked to, and often critical for, livelihoods and well-being. Furthermore, while natural areas provide vital regulating functions, the retention of these areas in cities has been largely haphazard and incidental. We are, however, witnessing the erosion of this resource base within larger cities, and areas further afield are now looked to in order to supply previously available resources. Forests in Maputo (Mozambique) have become significantly diminished, and charcoal is now supplied from as far away as the Gaza and Inhambane Provinces (200–500 km from the capital).

Associated with traditional urbanization trajectories, built infrastructure is usually designed and constructed for a single function and purpose. It tends to form a distinct barrier between natural and human activities, often undermining the function of natural systems to the perceived benefit of human health, mobility, livelihood and well-being. It has the added effect of establishing and locking-in further development patterns and social engagements, and once established, hard infrastructure is seldom removed or adapted, such as the canalization of river systems and the construction of settlements in wetlands (Elmqvist et al., 2018). Whilst the overwhelming benefits of built infrastructure to human well-being are clear (such as piped water to households), there are associated trade-offs, with some communities and natural systems negatively affected by such developments, either immediately or over time (e.g., through the construction of dams).

As is the case with many cities in the Global South, African cities are characterized by a high degree of informality (Myers, 2011). This applies to aspects of physical infrastructure, service delivery, livelihoods and governance. Here, natural areas and ecological infrastructure are influenced either positively or negatively by both the lack of a planned approach or formal planning mechanisms and the lack of regulation of these spaces. The conversion of natural systems to informal development is largely driven by the creation of roads and informal housing, with more than half of people in sub-Saharan African cities living in informal settlements (UN Habitat, 2013). These settlements are often located on valuable natural systems that have been kept undeveloped or protected by formal planning authorities. The rapid growth of populations and the expansion of informal settlements highlights the fact that social needs are a stronger political driver of urban development than environmental needs.

Governance and management (outlook)

African city contexts present a myriad of issues around poverty, gender inequality, economic growth and social justice (Swilling & Annecke, 2012). These are seen as social issues, and there is a lack of recognition of the direct links between ecological infrastructure and development solutions. The current and future potential role that ecological infrastructure plays in these solutions is unrecognized and perceived largely as a trade-off against purely social development issues (Cartwright & Oelofse, 2016). The arising externalities and ensuing costs following this approach, to replace functions like storm water remediation, are not adequately considered. The strategic planning of the built infrastructure in conjunction with ecological infrastructure is forgone in favour of dealing with immediate needs and the short-term planning cycles of politics. There are significant temporal disconnects between political and ecological cycles. This is perpetuated by planning on an issue-by-issue basis and needs to be addressed. The full spectrum of benefits that we derive from natural systems is not well documented, understood and considered in the policy formulation space. Issues relating to social justice and the role that natural spaces and resources play in service provision that supports social upliftment and social cohesion are poorly integrated into social development discourse and planning (Musango et al., 2017).

The ability to effectively govern African cities and therefore manage natural open space and ecological infrastructure has been confounded by a multitude of socioeconomic factors, including colonial legacies, corruption, war, unrest and tenure security issues. Many of the management systems that are in place are grounded and entrenched in systems based on historical inequalities that only serve to perpetuate many of these circumstances. Global governance, teleconnections, power relations with other countries, engineering standards and practices, resource use and foreign investments all combine in creating an inertia that holds current development trajectories in place. Power, politics, vested interests and competing development priorities affect budget allocations (Leck & Roberts, 2015). In African contexts, a lack of stability results in low levels of investment and poor economic growth, which means that budget allocations at the national and local levels for investment in natural open space and ecological infrastructure are limited. Increased population growth, affluence and associated consumption (Cobbinah et al., 2015) within and beyond the city combined with economic growth that is decoupled from resource consumption and environmental impact pose significant threats to sustainability (Swilling et al., 2013). Weak and poorly aligned governance structures result in poor coordination across different levels and spheres of government. Limited coordination can lead to both ineffectual and conflicting agendas that affect both the retention and quality of the remaining ecological infrastructure both within and beyond African cities. An example of conflict and dysfunction is visible when national governments are signatories to international treaties and conventions, but local authorities are actively responsible for implementing and promoting environmental transformation of the ecosystems to which these treaties speak.

Much of the policy and institutional formation that directs African urban development has been transplanted from the Global North (Watson, 2009). An example of this is the drive to remove informality in place of actively harnessing it, which has resulted in exclusion and the undermining of livelihoods. Across sub-Saharan Africa, there is inconsistent recognition of the need for environmental management portfolios within cities. Whilst there are downsides to having specific departments focusing on a crosscutting issue (e.g., irrigation within agricultural departments and climate change within environmental affairs departments), the consequences resulting from too few dedicated staff that focus on securing and integrating ecological infrastructure into planning for African cities is a serious impediment to progress. Those that exist are perceived as enforcing rigid management systems that are ill-positioned and ineffectual in dealing with the needs of residents. The failure to engage with stakeholders and understand their needs and challenges further limits the effectiveness of these authorities.

Knowing gaps and doing gaps

There is currently limited existing and available urban ecology research and data that can guide us in retaining and maintaining urban ecological infrastructure and ecological infrastructure beyond city boundaries. Whilst some good research has been done in this area (see Culwick et al., 2016; Hyman, 2013;

Schäffler & Swilling, 2013), it is generally agreed that there is not enough urban ecology research underway, both globally (Grimm *et al.*, 2008) but more specifically in African cities (McHale *et al.*, 2013). Persuading funders and education institutions of the importance of this research area is a critical task, and one that will also require a shift in the funding and publication systems that privilege the Global North (Ferrer *et al.*, 2018). The significance and relevance of research work in the field of urban ecology is often undervalued and therefore overlooked. Addressing this requires further advocacy by multiple stakeholders to encourage city practitioners to embrace an urban ecology lens. Baseline research that demonstrates the value of these systems from economic and social perspectives would make investment decisions around ecological infrastructure clearer.

In cases where research on urban ecology in Africa does exist, the application of this understanding is limited because in many instances governments lack the capacity and skills to act on the research findings and to develop and implement projects and programmes that respond to emerging knowledge. Consultants and practitioners are often relied on to fill in these gaps, initiating research activities and documenting and analysing processes. As a result, these skillsets fail to become entrenched within local government departments. This information, particularly case study work focused on specific cities or challenges in specific cities, is not available for research purposes as work is not being formally published in academic journals, but remains within the grey literature and therefore fails to be fully acknowledged within research contexts. Furthermore, there is limited coordination and sharing of the information that does exist (Culwick *et al.*, 2016). In this way, important research can fail to have broader policy-level impact.

In addition to these research issues, we lack critical data sets relating to ecological thresholds and tolerance levels, the plurality of values held by individuals for a range of ecosystem services and multiple variables around how services are produced. Data repositories and case study databases that are available to researchers in these regions would allow us to start filling in some of the identified gaps. Where data are available, we fail to use them in a way that highlights key issues such as the trade-offs and comparative 'costs' of different approaches to building city infrastructure and resourcing residents. If these direct links and different implications were better understood by decision-makers, they would more likely consider ecological issues in decision-making.

How to turn challenges into opportunities

Shifting African cities towards sustainable and resilient development trajectories that secure ecological infrastructure will require tackling aspects of the challenges described above. Here, we suggest three areas that need attention: (1) co-developing knowledge and allowing for experimentation; (2) mobilizing knowledge and messaging sustainability and resilience; and (3) developing or subverting institutions to allow for effective management and governance.

Developing knowledge: growing our case studies

The gaps in our knowledge need to be identified, acknowledged and shared. This will require sourcing and developing case studies and examples (both existing and new) that can demonstrate the worth of ecological infrastructure, successful interventions and circumstances for success and that establish an understanding of weak points where interventions have failed. Case studies that demonstrate how people, organizations and companies are coping with challenges and components of challenges relating to or through the use of ecological infrastructure will be especially useful. Ecological infrastructure studies need to be fostered across multiple scales (geographical, temporal and administrative) and will therefore require engagement with multiple levels of government. Identified examples of much-needed investigations include: identifying critical indicators of ecological infrastructure (both ecological and social) that would provide city-level insights; developing protocols for case study development that would enable the development of city typologies; urban metabolism studies that focus on sustainability interventions differentiated spatially across cities (Currie & Musango, 2016; 2017; Musango *et al.*, 2017); African regional tele-connections and tele-coupling studies that highlight both positive and erosive connections; understanding the opportunities for harmonizing urban planning and natural regimes; the role of modularization within African cities; and how to effectively create multipurpose and multifunctional spaces. Moreover, a multitude of urban experiments are required and we need enabling safe spaces for these (Allen *et al.*, 2016) in which the interests of researchers, citizens, civil society organizations and the private sector alike are secured.

All future work must engage with the system complexity inherent to the ecology of African cities, as well as the nexus properties of these issues. Water provides a natural entry point with respect to fostering understanding and opportunities around the natural and socioeconomic interface and securing political traction. Water is tightly coupled to environmental crises associated with climate change, natural hazards and disease and is most useful for exploring cross-scale linkages. This, in turn, can move research beyond silo thinking, management and action towards the development of integrated planning, design and infrastructure deployment systems (Chen & Lu, 2015; Chirisa & Bandauko, 2015; Wang & Chen, 2016). Nexus thinking takes us beyond the 'binary' of informal and formal development by focusing on understanding the wider framing of interdependent socio-ecological infrastructures.

Accessing and mobilizing knowledge

Existing and new knowledge needs to be placed in repositories that are accessible to a diversity of people including researchers, practitioners and civil society. Case studies should seek to pilot small-scale ideas and emergent solutions that combine and mobilize knowledge across all sectors, including types of knowledge that were not previously considered. The opportunity for using new and innovative technologies to build knowledge also needs to be explored. In light of weak governance and opaque decision pathways, knowledge can most effectively be mobilized through the knowledge generation process itself. Ecological infrastructure research needs to change in form and focus to simultaneously grow knowledge and communities of practice. Research should seek to be iterative, dynamic, engaging and empowering, following a route of knowledge co-generation and co-learning. Work within the *cities climate adaptation* space indicates that these approaches also prove cost effective (Cartwright *et al.*, 2013). Community-based organizations and civil society organizations that are already established can be useful in creating linkages, driving further change and facilitating the sharing of knowledge.

Developing and subverting institutions

It is unlikely that governments will invest significant resources in top-down or national-level solutions for the effective retention

and maintenance of ecological infrastructure in the Global South. Solutions moving ahead will therefore require developing and/or subverting existing organizations and institutions to facilitate knowledge sharing and action on this issue. Growing research and knowledge-generation capabilities in this space requires uptake in curricula across a diversity of education institutions. Coordination and network weaving across researchers and practitioners in and across African cities will be a key focus here in ensuring that information is captured and shared. Spaces and conditions at different scales, both formal and informal, need to be created and fostered so that people championing potential solutions can emerge and novel and effective partnerships can be established. Linking together small-scale interventions and actions should also be explored in terms of upscaling possibilities and benefitting from synergies. A number of urban organizations are operating along the lines noted above, such as Women in Informal Employment: Globalizing and Organizing (WIEGO) and Slum Dwellers International (SDI), but not in relation to ecological infrastructure. There are opportunities to learn from or engage with these organizations towards research and action for improved urban sustainability in African cities.

There needs to be a move away from hard institutional lock-in, particularly within the context of political instability. Engaging with integrated land use and the multifunctional nature of landscapes can potentially find synergies within unregulated and informal land-use practices. Built infrastructure developments need to take consideration of – and possibly be directed by – ecological infrastructure before developments are undertaken (Elmqvist *et al.*, 2018).

The multiple potential functions and benefits that ecological infrastructure can provide, such as regulating water flows, providing recreation opportunities or locating spiritual activities, require consideration. Whilst African cities are rapidly expanding, we still have opportunities to integrate this thinking into our development processes. Determining how to include ecological systems and assets into municipal budgeting and planning processes is urgently needed. Collective long-term visions that acknowledge the plurality of value associated with functioning ecosystems and ecological infrastructure (Pascual *et al.*, 2017) need to be established. Simultaneously, opportunities to address short-term urgent needs in a way that does not undermine this long-term vision need to be sought. Informal networks of people or structures, even discussion fora, can guide and facilitate the structuring of city spaces or managing sections of city landscapes such that they enhance ecological infrastructure and ecosystem benefit flows. The degree to which this needs to happen in the overall context of a higher-level plan needs to be considered so that upstream and downstream factors remain neutral or potentially beneficial. Such processes run counter to the modernist, Global North's view of what a city is and should be (Watson, 2014) and are likely to be met with a high level of opposition within both local governments and non-governmental sectors. Here, art and design can lead the way in collectively imagining future African cityscapes.

Final thoughts

There are significant opportunities to retain and maintain ecological infrastructure and to use it to enhance well-being in African cities, but there are a number of fundamental challenges that must first be addressed. Addressing these will require much creativity and ingenuity, and likely will involve the adoption of multiple different types of interventions at different scales where resilience frameworks and principles provide overarching guidance. Significant progress is likely to come from multiple small-scale, local-level interventions in which leadership is demonstrated through action. Where small-scale interventions are insufficient to deal with macro-challenges, governments will need to play a role in directing large-scale interventions. Access to natural resources, trade-offs relating to their use versus alternatives and trade-offs between different community objectives will need to be understood in great detail in order to manage systems such that issues of justice and equity become a central focus in building resilience. The African context provides an alternative and new learning opportunity that could help us understand not only the 'African' case, but all cities and their future developments.

References

Adelekan, I., Johnson, C., Manda, M., Matyas, D., Mberu, B., Parnell, S., … Vivekananda, J. (2015). Disaster risk and its reduction: an agenda for urban Africa. *International Development Planning Review*, 37, 33–43.

Adesina, A.A., Gurria, A., Clark, H. (2016). African Economic Outlook. AfDB, OECD, UNDP. Retrieved from https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/AEO_2016_Report_Full_English.pdf.

Allen, A., Swilling, M., & Lampis, A. (eds) (2016). *Untamed Urbanisms. Routledge Advances in Regional Economics, Science and Policy*. Routledge.

Anderson, P., Brown-Luthango, M., Cartwright, A., Farouk, I., & Smit, W. (2013). Brokering communities of knowledge and practice: reflections on the African Centre for Cities' CityLab programme. *Cities*, 32, 1–10.

Biggs, R., Schlüter, M., & Schoon, M.L. (eds) (2015). *Towards Principles for Building Resilience: Sustaining Ecosystem Services in Social-Ecological Systems*. Cambridge University Press.

Boadi, K., Kuitunen, M., Raheem, K., & Hanninen, K. (2005). Urbanisation without development: environmental and health implications in African cities. Environment, Development and Sustainability, 7(4), 465–500.

Cartwright, A., Blignaut, J., De Wit, M., Goldberg, K., Mander, M., O'Donoghue, S., & Roberts, D. (2013). Economics of climate change adaptation at the local scale under conditions of uncertainty and resource constraints: the case of Durban, South Africa. *Environment and Urbanisation*, 25(1), 1–19.

Cartwright, A., & Oelofse, G. (2016). Reflections on the valuing of ecosystem goods and services in Cape Town. In C. Culwick, K. Bobbins, A. Cartwright, G. Oelofse, M. Mander, & S.A. Dunsmore (eds), *A Framework for a Green Infrastructure Planning Approach in the Gauteng City-Region (GCRO Research Report)* (pp. 40–59). Gauteng City-Region Observatory.

CBO (2012). *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment*. Springer.

Chen, B., & Lu, Y. (2015). Urban nexus: a new paradigm for urban studies. *Ecological Modelling*, *318*, 5–7.

Chirisa, I., & Bandauko, E. (2015). African Cities and the water–food–climate–energy nexus: an agenda for sustainability and resilience at a local level. *Urban Forum*, *26*(4), 391–404.

Cobbinah, P.B., & Darkwah, R.M. (2016). African urbanism: the geography of urban greenery. *Urban Forum*, *27*(2), 149–165.

Cobbinah, P.B., Erdiaw-Kwasie, M.O., & Amoateng, P. (2015). African urbanisation: implications for sustainable development. *Cities*, *47*, 62–72.

Cilliers, S., Cilliers, J., Lubbe, R., & Siebert, S. (2013). Ecosystem services of urban green spaces in African countries – perspectives and challenges. *Urban Ecosystems*, *16*, 681–701.

Culwick, C., Bobbins, K., Cartwright, A., Oelofse, G., Mander, M., & Dunsmore, S. (2016). *A Framework for a Green Infrastructure Planning Approach in the Gauteng City-Region (GCRO Research Report)*. Gauteng City-Region Observatory.

Currie, P.K., & Musango, J.K. (2016). African urbanization: assimilating urban metabolism into sustainability discourse and practice: African urbanization. *Journal of Industrial Ecology*, *21*(5), 1262–1276.

Currie, P.K., Musango, J.K., & May., N.D. (2017). Urban metabolism: a review with reference to Cape Town. *Cities*, *70*, 91–110.

Elmqvist, T., Siri, J., Andersson, E., Anderson, P., Bai, X., Das, P.K., … Török, E.H. (2018). Urban tinkering. *Sustainability Science*, *13*(6), 1549–1564.

Ferrer, A.L.C., Thomé, A.M.T., & Scavarda, A. J. (2018). Sustainable urban infrastructure: a review. *Resources, Conservation and Recycling*, *128*, 360–372.

Gómez-Baggethun, E., Gren, A., Barton, D.N., Langemeyer, J., McPhearson, T., O'Farrell, P., … Kremer, P. (2013). Urban ecosystem services. In *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment* (pp. 175–251). Springer.

Grimm, N.B., Faeth, S.H., Golubiewski, N., Redman, C.L., Wu, J., Bai, X., & Briggs, J.M. (2008). Global change and the ecology of cities. *Science*, *319*, 756–760.

Guneralp, B., Lwasa, S., Masundire, H., Parnell, S., & Seto, K.C. (2017). Urbanization in Africa: challenges and opportunities for conservation. *Environmental Research Letter*, *13*, 1.

Hyman, K. (2013). Urban infrastructure and natural resource flows: evidence from Cape Town. *Science of the Total Environment*, *461–462*, 839–845.

Leck, H., & Roberts, D. (2015). What lies beneath: understanding the invisible aspects of municipal climate change governance. *Current Opinion in Environmental Sustainability*, *13*, 61–67.

McHale, M.R., Bunn, D.N., Pickett, S.T., & Twine, W. (2013). Urban ecology in a developing world: why advanced socioecological theory needs Africa. *Frontiers in Ecology and the Environment*, *11*(10), 556–564.

Meerow, S., & Newell, J.P. (2019). Urban resilience for whom, what, when, where, and why? *Urban Geography*, *40*(3), 309–329.

Musango, J., Currie, P., & Robinson, B. (2017). *Urban Metabolism for Resource Efficient Cities: From Theory to Implementation*. UN Environment.

Myers, G. (2011). *African Cities: Alternative Visions of Urban Theory and Practice*. Zed Books.

Parnell, S., & Walawege, R. (2011). Sub-Saharan African urbanisation and global environmental change. *Global Environmental Change*, *21*, S12–S20.

Pascual, U., Balvanera, P., Díaz, S., Pataki, G., Roth, E., Stenseke, M., … Yagi, N. (2017). Valuing nature's contribution to people: the IPBES approach. *Current Opinion in Environmental Sustainability*, *26*, 7–16.

Pieterse, E. (2006). Building with ruins and dreams: exploratory thoughts on realizing integrated urban development through cities. *Urban Studies*, *43*(2), 285–304.

Pieterse, E. (2009). *Exploratory Notes on African Urbanism*. African Center for Cities.

Pieterse, E. (2011). Grasping the unknowable: coming to grips with African urbanisms. *Social Dynamics*, *37*, 5–23.

SANBI (2014). *A Framework for Investing in Ecological Infrastructure in South Africa*. South African National Biodiversity Institute.

Schäffler, A., & Swilling, M. (2013). Valuing green infrastructure in an urban environment under pressure – the Johannesburg case. *Ecological Economics*, *86*, 246–257.

Seto, K.C., Fragkias, M., Güneralp, B., & Reilly, M.K. (2011). A meta-analysis of global urban land expansion. *PLoS ONE*, *6*(8), e23777.

Swilling, M. (2016). Africa's game changers and the catalysts of social and system innovation. *Ecology and Society*, *21*(1), 37.

Swilling, M., & Annecke, E. (2012). *Just Transitions: Explorations of Sustainability in an Unfair World*. University of Cape Town Press.

Swilling, M., Robinson, B., Marvin, S., & Hodson, M. (2013). City-level decoupling: urban resource flows and the governance of infrastructure transitions. United Nations Environment Programme, and International Resource Panel. Retrieved from https://www.wrforum.org/uneppublicationspdf/city-level-decoupling-urban-resource-flows-and-the-governance-of-infrastructure-transitions.

UN-DESA (2014). World Urbanization Prospects: The 2014 Revision. New York. Retrieved from http://esa.un.org/unpd/wup.

UN Habitat (2013). *State of the World's Cities 2012/2013: Prosperity of Cities*. Routledge.

Wang, S., & Chen., B. (2016). Energy–water nexus of urban agglomeration based on multiregional input–output tables and ecological network analysis: a case study of the Beijing–Tianjin–Hebei region. *Applied Energy*, *178*, 773–783.

Watson, V. (2009). 'The planned city sweeps the poor away…': urban planning and 21st century urbanisation. *Progress in Planning*, *72*, 151–193.

Watson, V. (2014). African urban fantasies: dreams or nightmares? *Environment and Urbanization*, *26*(1), 215–231.