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Resilience of and through urban ecosystem services

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ABSTRACT

Cities and urban areas are critical components of global sustainability as loci of sustainability progress and drivers of global transformation, especially in terms of energy efficiency, climate change adaptation, and social innovation. However, urban ecosystems have not been incorporated adequately into urban governance and planning for resilience despite mounting evidence that urban resident health and wellbeing is closely tied to the quality, quantity, and diversity of urban ecosystem services. We suggest that urban ecosystem services provide key links for bridging planning, management and governance practices seeking transitions to more sustainable cities, and serve an important role in building resilience in urban systems. Emerging city goals for resilience should explicitly incorporate the value of urban ES in city planning and governance. We argue that cities need to prioritize safeguarding of a resilient supply of ecosystem services to ensure livable, sustainable cities, especially given the dynamic nature of urban systems continually responding to global environmental change. Building urban resilience *of* and *through* ecosystem services, both in research and in practice, will require dealing with the dynamic nature of urban social–ecological systems and incorporating multiple ways of knowing into governance approaches to resilience including from scientists, practitioners, designers and planners.

1. Introduction

Cities and urban areas are critical to global sustainability since they are the locus of much of the sustainability progress and are drivers of change, especially in terms of energy efficiency (Slavin, 2011), climate change adaptation (Rosenzweig and Solecki, 2010), and social innovation (Bettencourt et al., 2007). Many cities have sustainability plans, but have not specifically addressed urban resilience, or if they have, often conflate or use sustainability and resilience interchangeably (Redman, 2014). Lack of resilience to social, ecological, and economic disturbances can shift urban system trajectories away from sustainability. Recently however, improving specific resilience (Carpenter et al., 2001), especially in sensitive areas of urban systems experiencing climate change, urbanization, and development pressures, is of increasing concern with cities beginning to develop specific plans and resilience targets (Solecki et al., 2011; PlaNYC, 2013), especially for reducing disaster risks and vulnerabilities to climate change (Pickett et al., 2004; Elmqvist et al., 2014). For example, the Mayor's office of New York City responded to the widespread damage from Hurricane Sandy (2012) by creating a high-level "Special Initiative for Rebuilding and Resiliency" (New York City Special Initiative for Rebuilding and Resiliency (NYCSIRR): New York City Office of the Mayor, 2013). Many other motivated mayors, urban planners, and designers are increasingly considering how new development plans and projects can contribute to and foster resilience to climate change and it's myriad effects (Rosenzweig et al., 2010). In coastal cities for example, mitigating and planning for disasters and effects of sea level rise including coastal flooding and storm surge is a growing mandate (Rosenzweig et al., 2011)

Resilient supply of non-disaster related ecosystem services (ES) provided within urban areas has received little attention. Though some cities are beginning to consider how ecosystems in cities can help mitigate climate change effects or create spaces that increase existing adaptive capacity for post-effect recovery, in most global cities services provided by urban ecosystems remain poorly connected to urban planning, design, and management for resilience (Scarlett and Boyd, 2013). We argue that cities will need to plan and manage urban ecosystems for enduring supply of services in dynamic urban systems affected by global environmental change. Therefore, we propose that ES and resilience are related in two ways: First, resilience can be fostered by incorporating the concept of ES in urban planning, design and management of urban social–ecological systems. Second, cities need to safeguard resilient supply of ES in the long-term to ensure urban human well-being (Fig. 1). For these reasons we suggest that urban ES provide a key

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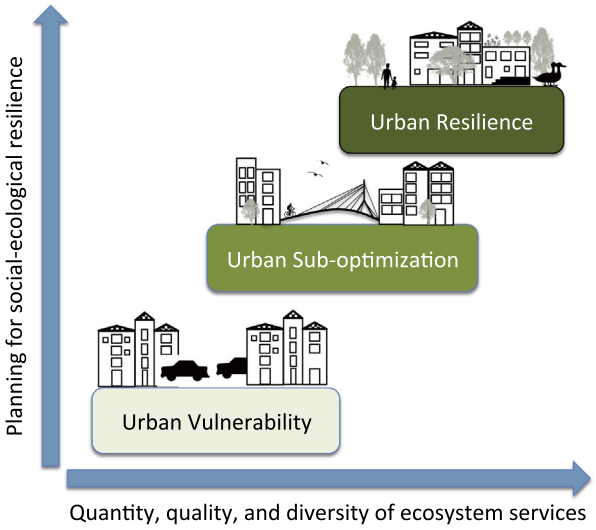

Fig. 1. Urban resilience can be fostered by incorporating urban ES in planning, design and management of urban social–ecological systems. A social–ecological approach for cities is critical to safeguard a resilient supply of ES in the long-term to ensure urban human well-being (Schewenius et al., 2014; Elmqvist et al., 2014). However, safeguarding urban ES requires recognizing and incorporating the multiple values of ES in planning and governance. As urban planning and governance for social–ecological resilience increases, together with conservation of and management for increased quality, quantity, and diversity of urban ES, resilience at multiple scales can be improved.

entry point (Andersson et al., 2015) for planning, management and governance practices seeking increased resilience and transitions towards urban sustainability (Frantzeskaki and Tilie, 2014).

2. Sustainability, resilience, and urban ecosystem services

Though governance practices and planning approaches for urban sustainability must consider the large urban footprint to improve sustainability, here we focus on the internal footprint of cities and specifically the sustainable production of ES in the city. Urban ES provide important ways for improving sustainability by locally providing services to urban residents, decreasing reliance on externally produced services, and thus decreasing the global footprint of cities. Such urban ES include local food and water production (Gómez-Baggethun et al., 2013), and utilizing green infrastructure in place of environmentally and economically costly grey infrastructure for reducing impacts of stormwater on urban drainage systems therefore lowering the risk of surface water flooding (Kaye et al., 2006; Pataki et al., 2011; Alamarie et al., 2010; McPhearson et al., 2013a). There are also many ES critical to human health and wellbeing that cannot be imported and must be supplied locally within urban ecosystems (McPhearson et al., 2013b; Andersson et al., 2015), for example utilizing urban parks, green walls and roofs, and street trees to offset urban heat islands and thereby reducing energy use for cooling (Gill et al., 2007; Pataki et al., 2011), or the mental and physical health benefits provided by urban green infrastructure (Gómez-Baggethun et al., 2013).

Overall, urban ecosystems provide a large roster of critical services affecting human health and wellbeing in cities (Elmqvist et al., 2013; Gómez-Baggethun et al., 2013; McPhearson et al., 2014). However, while research to predict and understand urban climate change is expanding rapidly (Rosenzweig et al., 2011), we still know little about how climate change will affect urban biodiversity and the ecological structure, functions, and services that affect human livelihoods in cities (Solecki and Marcotullio, 2013). Urban ES may be vulnerable to change, whether by land use change and development or from other sources of change including climate change, extreme events, or political and economic change (Seto et al., 2012). Further research is needed to understand how climate interacts with and drives changes in urban ecosystems, and therefore how these changes will affect the supply of ES. We need to understand the resilience *of* urban ES, and how it is linked to global and local social–ecological changes as well as how changes in urban ES feedback to impact resilience within urban systems at multiple scales.

Resilience is generally considered in the context of response to sudden impacts like natural disasters (Alberti et al., 2003; Pickett et al., 2004). However, the resilience concept is not limited to recovery from a single disturbance. Resilience is a multidisciplinary concept that encompasses persistence, recovery, and the adaptive and transformative capacities of social–ecological systems and subsystems (Holling, 2001; Walker et al., 2004; Biggs et al., 2012). Improving resilience at both small and large system scales depends on answering the question of resilience "of what, to what" (Carpenter et al., 2001), and, perhaps especially in urban areas, resilience "for whom" (Pickett et al., 2011). Including urban ES in resilience planning and management can help to address these questions. Below we discuss three overlapping ways to help to connect urban ES to resilience in urban systems.

2.1. Insurance and option values

The value of resilience through urban ecosystems has so far not been included in urban ecosystem services valuation and assessment. We suggest insurance and option values as two key aspects for connecting urban ES to resilience in valuation studies, and that accounting for both insurance value and option value of ecosystems in urban resilience targets will both increase the likelihood that ecosystems are managed for resilient supply of services, and that resilience targets will be met. While multiple definitions exist, we propose that insurance value reflects "the maintenance of ecosystem service benefits despite variability, disturbance and management uncertainty". Therefore, the insurance value of an ecosystem is closely related to its resilience, self-organizing capacity, and to what extent it may continue to provide flows of ecosystem service benefits over a range of variable environmental conditions. Option value instead focuses on the maintenance of alternative uses or solutions and the reversibility of decisions (Pascual et al., 2010). For example, multifunctional green infrastructure allows for different uses and for different ecosystem service benefits that can be utilized at different times. A well-known case is how urban parks were used for food production instead of recreation during the two World Wars (Barthel et al., 2013). Less dramatic changes in how ecosystems are used and valued include shifts from regulating services to recreational services (e.g. wetlands in the Kristianstad Vattenrike Biosphere Reserve, Sweden) (Olsson and Galaz, 2009).

2.2. Resilience through urban ecosystem services

High population density, high connectivity and dependence on infrastructure can make urban populations vulnerable to disturbances, such as flooding, heat waves, disease outbreaks, land slides, and storms (Peters et al., 2004). Ecosystems within and around cities can provide insurance by helping to buffer against many of these disturbances. Resilience to specific events, whether climate mediated or not, may arise through ES where benefits occur during or shortly after the event. This specified resilience could be understood and addressed through urban planning and management targeting green infrastructure and associated ES. For example, mangroves and

wetlands can provide resilience to nearby communities to the effects of storm surges, and urban green infrastructure can provide resilience during heat waves by providing cooling (TEEB, 2011). Therefore, resilience can be improved *through* multiple types of urban ES, which provide resilience to specific events. Some urban ES may also provide resilience to other social–ecological system changes that take place over the long-term (Cumming et al., 2012), though this is an area in need of additional research.

Urban ecosystems, including all urban green and blue infrastructure, together with their feedbacks, cycles, and dynamics, can be utilized for strengthening the feedback between people and ES supply. However, we still need to know more about how social and ecological aspects of resilience are related to each other as well as how they are supported through urban ecosystems. For example, cases of biophilia (Tidball and Stedman, 2013), where people respond to disturbances by improving ecological spaces for both social and ecological benefit, could be further explored and incorporated into planning and management for resilience. Additionally, since urban ES are highly influenced by cultural preferences, traditions, and social values (Andersson et al., 2007, 2014; Grove et al., 2006; McPhearson et al., 2013b), building resilience through ES requires understanding the social and ecological drivers of ES. As summarized by Andersson et al., (2015) local generation of urban ES, especially cultural ES, can help in engaging people and inspire stewardship, both key for building resilience (e.g. Chapin et al., 2011; Colding and Barthel, 2013; Folke et al., 2011). As planners and managers better understand the importance of cultural ES, their value, and links to urban residents at the local and citywide scale, planners and managers should be able to begin examining and improving resilience by managing ES to meet culturally driven urban ES demand.

2.3. Resilience of urban ecosystem services

Not only do we need ES to help build resilience for cities, we also need the generation of ES themselves to be resilient. After two decades of research on the relationship between biodiversity and ecosystem functioning (Cardinale et al., 2012) we know that diversity often compensates for fluctuations in individual species populations and the functions they perform within their systems (Chapin et al., 1997; Yachi and Loreau, 1999). Many ecosystem functions are beneficial to humans and can be translated into ES. Biodiversity can thus be expected, in most cases, to buffer the impact disturbances have on ecosystem service generation (Ibid). However, there are several layers of complexity to this relationship, perhaps especially in urban areas. First, humans are deeply involved in the generation of urban ES, which are coproduced by people and ecosystems (Ernston, 2013; Andersson et al., 2015), and changes in management regimes or ecosystem use patterns may profoundly change which ES an urban ecosystem can deliver. Second, compensatory mechanisms either in species communities or human use or stewardship of ecosystems rely on differentiated response to disturbances. If all species, humans included, react in the same way to a certain disturbance there will be a systemic change, regardless of how diverse the system is (Elmqvist et al., 2003). Therefore, resilience of ES can be hypothesized to require both biodiversity and a diversity of responses.

Additionally, increasing our understanding of how ES supply can be matched spatially and temporarily with demand can affect resilience of social systems. Ensuring resilient supply of urban ES, including retaining the capacity to accommodate changing demands, is part of sustainable urban ES production. To improve resilience of the accessible supply of ecosystem services at multiple spatial scales means that planners and managers need to recognize the context dependent nature of ecosystem service production, including social, cultural, ecological, and event contexts (Andersson et al., 2015).

3. Connecting urban ecosystem services to governance

Policy and planning regimes organize the processes of strategies formulation and goal selection that guide which and how urban ES are considered (Hansen et al., 2015). Currently, there is limited knowledge on how such planning processes, with their own historical timelines and path-dependencies as well as their context-dependent drivers and barriers, relate to and impact aspects of ES related to urban resilience or the uptake of urban ES and resilience concepts in governance practices (Wilkinson et al., 2013; Erixon et al., 2014; Gómez-Baggethun et al., 2013; Frantzeskaki and Tilie, 2014).

Understanding and addressing resilience *through* and *of* urban ES may enable urban planning and governance to become adaptive and reflexive not only to external drivers (e.g. climate change extremes and vulnerabilities) but also to internal drivers. We suggest that future research needs to provide the foundations for informing a dynamic governance approach that considers both social and ecological dynamics in order to build resilience through and for urban ES (Schewenius et al., 2014). For example, enabling citizens to take up initiatives for restoring green infrastructure in urban neighborhoods can act in synergy with city plans to add permeable surfaces, and in this way increase stormwater absorption/retention in urban spaces. New York City recently offered US $6 million to fund private property owners to do exactly this (NYC Department of Environmental Protection, 2014). These kinds of governance practices can provide opportunities for utilizing urban ES and building urban resilience reflexively to meet multiple needs including not only stormwater absorption, but also supporting spaces that can create a sense of community, social cohesion and inclusiveness in cities.

4. Conclusions: Bridging the gap for urban resilience and ecosystem services

The health and wellbeing of urban residents depend on locally produced ES. Resilient supply of those services in the face of global environmental and other changes is important to achieving sustainability goals being set in cities. Additionally, given the large environmental footprints of cities, protection and sustainable use of ecosystems in cities and urban regions are key components of global sustainable development. Still, despite new research and emerging science-policy platforms (Schewenius et al., 2014), safeguarding biodiversity and ES in urban areas remains disconnected from resilience in urban planning.

Managing urban ecosystems for resilient supply of urban ES, including retaining the flexibility to accommodate changing demands, is part of sustainable urban ES production. However, the social–ecological coproduction of ecosystem services are context dependent and require dealing with the inherent complexity of not only ecological dynamics, but also human perception, values, and cultural traditions affecting the supply and demand of ES. Urban planners and managers need to better understand and articulate the multiple values of urban ES in order to improve resilience at neighbourhood and even city scales.

Additionally, it's not just disasters or climate change driven events, such as storm surges or heat waves that influence resilience within cities. Resilience also concerns a larger suite of urban ES that provide benefits to urban livelihoods and wellbeing. Even aesthetic benefits of urban green infrastructure may affect resilience to social, ecological, or economic change. For example, it

is well known that real estate near urban parks is often of higher economic value than comparable real estate elsewhere (Sander et al., 2010; Troy and Grove, 2008). However, aesthetics, sense of place, recreation, and other benefits associated with, for example owning a home near an urban park, may also provide resilience to fluctuations in real estate prices. It will be important for planners and managers to move beyond focusing on disaster resilience to instead open up to and allow for adaptive management and planning that can connect long-term sustainability visions to short-term and medium-term stewardship of urban ES that provide resilience.

Our main purpose here is to suggest that resilience focused planning, management and governance will be better served by including ecosystem services explicitly in resilience approaches. Improving resilience in urban systems, both in research and in practice, requires that we deal with the complex nature of and interactions within urban social–ecological systems (McPhearson, 2014). Incorporating insurance and option value into valuation assessments of ecosystem services and the benefits of investing in insurance capacity of urban ecosystems provide opportunities for incorporating urban ES in governance for resilience. However, we recognize that policy and planning processes are context-dependent with distinct dynamics that affect aspirations for integrating urban ES and advocating urban ES-oriented planning (de Groot et al., 2010). We suggest that linking research on urban resilience to urban ES is an important pathway for improving the capacity and efficacy of urban governance for resilience.

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References

Alamarie, K., Coh, A., Larry dela Cruz, J., Donnelly, H., Eckels, M., Farag, M., Garcia, K., 2010. NYC Green Infrastructure Plan—A Sustainable Strategy for Clean Waterways, 1–154 (New York).

Alberti, M., Marzluff, J.M., Schulenberger, E., Bradley, G., Ryan, C., Zumbrunnen, C., 2003. Integrating humans into ecology: opportunities and challenges for studying urban ecosystems. BioScience 53 (12), 1169–1179.

Andersson, E., Barthel, S., Ahrné, K., 2007. Measuring social–ecological dynamics behind the generation of ecosystem services. Ecol. Appl. 17, 1267–1278.

Andersson, E., Barthel, S., Borgström, S., Colding, J., Elmqvist, T., Folke, C., Gren, Å, 2014. Reconnecting cities to the biosphere: stewardship of green infrastructure and urban ecosystem services. Ambio 43 (4), 445–453. http://dx.doi.org/10.1007/s13280-014-0506-y.

Andersson, E., M. Tengö, T. McPhearson, P. Kremer, 2015. Cultural ecosystem services as a platform for working towards urban sustainability. Ecosyst. Serv. 12, 165–168, accepted.

Andersson, E., T. McPhearson, P. Kremer, E. Gomez-Baggethun, D. Haase, M. Tuvendal, D. Wurster, 2015. Scale and context dependence of ecosystem service providing units. Ecosyst. Serv. 12, 157–164, accepted.

Barthel, S., Parker, J., Ernstson, H., 2013. Food and green space in cities: a resilience lens on gardens and urban environmental movements. Urban Stud , http://dx.doi.org/10.1177/0042098012472744.

Bettencourt, L.M.A, Lobo, J., Helbing, D., Kühnert, C., West, G.B., 2007. Growth, innovation, scaling, and the pace of life in cities. Proc. Nat. Acad. Sci. U.S.A. 104 (17), 7301–7306.

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

Cardinale, B.J., Duffy, J.E, Gonzalez, A., Hooper, D.U., Perrings, C., Venail, P., Narwani, A, Mace, G.M., Tilman, D., Wardle, D.A., Kinzig, A.P., Daily, G.C., Loreau, M., Grace, J.B., Larigauderie, A., Srivastava, D.S., Naeem, S., 2012. Biodiversity loss and its impact on humanity. Nature 486, 59–67. http://dx.doi.org/10.1038/nature11148.

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

Chapin III, F. Stuart, Power, Mary E., Pickett, Steward T.A., Freitag, Amy, Reynolds, Julie A., Jackson, Robert B., Lodge, David M., Duke, Clifford, Collins, Scott L., Power, Alison G., Bartuska, Ann, 2011. Earth Stewardship: science for action to sustain the human-earth system. Ecosphere 2 (8).

Chapin, F.S.III, Walker, B.H., Hobbs, R.J., Hooper, D.U., Lawton, J.H., Sala, O.E., Tilman, D., 1997. Biotic control over the functioning of ecosystems. Science 277, 500–504. http://dx.doi.org/10.1126/science.277.5325.500.

Colding, J., Barthel, S., 2013. The potential of "Urban Green Commons" in the resilience building of cities. Ecol. Econ. 86, 156–166. http://dx.doi.org/10.1016/j.ecolecon.2012.10.016.

Cumming, G.S., Olsson, P., Chapin III, F.S., Holling, C.S., 2012. Resilience, experimentation and scale mismatches in social–ecological landscapes. Landscape Ecol. 28 (6), 1139–1150. http://dx.doi.org/10.1007/s10980-012-9725-4.

de Groot, R.S., Alkemade, R., Braat, L., Hein, L., Willemen, L., 2010. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecol. Complexity 7, 260–272.

Elmqvist, T., Folke, C., Nyström, M., Peterson, G., Bengtsson, Jan, Walker, B., Norberg, J., 2003. Response diversity, ecosystem change, and resilience. Front. Ecol. Environ. 1 (9), 488–494.

Elmqvist, T., Fragkias, M., Goodness, J., Güneralp, B., Marcotullio, P.J., Mcdonald, R.I., Wilkinson, C., 2013. Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities. Springer, Dordrechthttp://dx.doi.org/10.1007/978-94-007-7088-1.

Elmqvist, T., Barnett, G., Wilkinson, C., 2014. Exploring urban sustainability and resilience. In: Roberts, P., Newton, P, Pearson, L. (Eds.), Resilient Sustainable Cities A Future. Routledge, New York, pp. 19–28.

Erixon, H., Borgström, S., Andersson, E., 2014. Challenging dichotomies—exploring resilience as an integrative and operative conceptual framework for large-scale urban green structures. Plann. Theory Pract. 3, 349–372. http://dx.doi.org/10.1080/14649357.2013.813960.

Ernston, H., 2013. The social production of ecosystem services: a framework for studying environmental justice and ecological complexity in urbanized landscapes. Landscape Urban Plann. 109, 7–17.

Folke, C., Jansson, Å., Rockström, J., Olsson, P., Carpenter, S.R., Chapin, F.S., Crépin, A.-S., Daily, G., Danell, K., Ebbesson, J., Elmqvist, T., Galaz, V., Moberg, F., Nilsson, M., Österblom, H., Ostrom, E., Persson, Å., Peterson, G., Polasky, S., Steffen, W., Walker, B., Westley, F., 2011. Reconnecting to the biosphere. AMBIO 40, 719–738.

Frantzeskaki, N., Tilie, N., 2014. The dynamics of urban ecosystem governance in Rotterdam, The Netherlands. AMBIO 43, 542–555. http://dx.doi.org/10.1007/s13280-014-0512-0.

Gill, S.E., Handley, J.F., Ennos, A.R., Pauleit, S., 2007. Adapting cities for climate change: the role of the green infrastructure. Built Environ. 33 (1) (155-133).

Gómez-Baggethun, E., Gren, Å., Barton, D.N., Langemeyer, J, McPhearson, T, O'Farrell, P, Andersson, E, Hamstead, Z, Kremer, P., 2013. Urban ecosystem services,. In: Elmqvist, T., et al. (Eds.), In: Cities and Biodiversity Outlook: Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities. Springer, Netherlands, pp. 175–251. http://dx.doi.org/10.1007/978-94-007-7088-1_11.

Grove, J., Troy, A., O'Neil-Dunne, J., Burch, W.R., Cadenasso, M., Pickett, S.T.A., 2006. Characterization of Households and its implications for the vegetation of urban ecosystems. Ecosystems 9, 578–597.

Hansen, R., N. Frantzeskaki, T. McPhearson, E. Rall, N. Kabisch, A. Kaczorowska, J. Kain, M. Artmann, S. Pauleit, 2015. The uptake of the ecosystem services concept in planning discourses of European and American cities. Ecosyst. Serv. 12, 228–246, accepted.

Holling, C.S., 2001. Understanding the complexity of economic, ecological, and social systems. Ecosystems 4 (5), 390–405.

Kaye, J.P., et al., 2006. A distinct urban biogeochemistry? TREE. 21 (4), 192–199 http://biology.duke.edu/wilson/EcoSysServices/papers/KayeEtal2006.pdf.

McPhearson, T., 2014. An urban ecology approach to "The Future We Want". Rev. Mag. 11, 18–24.

McPhearson, T., Hamstead, Z., Kremer, P., 2014. Urban ecosystem services for resilience planning and management in New York City. AMBIO: J. Hum. Environ. 43 (Special Issue), 502–515. http://dx.doi.org/10.1007/s13280-014-0509-8.

McPhearson, T., Maddox, D., Gunther, B., Bragdon, D., 2013a. New York City biodiversity, green space, and ecosystem services. In: Elmqvist, T., et al. (Eds.), In: Cities and Biodiversity Outlook: Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities. Springer, Netherlands, pp. 355–383. http://dx.doi.org/10.1007/978-94-007-7088-1_19.

McPhearson, T., Kremer, P., Hamstead, Z., 2013b. Mapping ecosystem services in New York City: applying a social–ecological approach in urban vacant land. Ecosyst. Serv., 11–26.

New York City Special Initiative for Rebuilding and Resiliency (NYCSIRR): New York City Office of the Mayor. 2013. PlaNYC A Stronger, More Resilient New York, New York. NY: NYC Mayor's Office. Available from ⟨http://www.nyc.gov/html/sirr/html/report/report.shtml⟩.

NYC Department of Environmental Protection. 2014. Grant Program for Private Property Owners. Accessed on 3-21-2104 ⟨http://www.nyc.gov/html/dep/html/stormwater/nyc_green_infrastructure_grant_program.shtml⟩.

Olsson, P., Galaz, V., 2009. Transitions to adaptive water management and governance in Sweden. In: Huitema, D., Meijerink, S. (Eds.), Understanding Transitions in Water Management. Edward Elgar Publishing.

Pascual, U., Muradian, R., Brander, L., Gómez-Baggethun, E., Martín-López, B., Verma, M., Armsworth, P., Christie, M., Cornelissen, H., Eppink, F., Farley, J., Loomis, J., Pearson, L., Perrings, C., Polasky, S., 2010. The economics of valuing ecosystem services and biodiversity. In: Kumar, P. (Ed.), The Economics of Ecosystems and Biodiversity TEEB Ecological and Economic Foundations. TEEB.

Pataki, D.E., Carreiro, M.M., Cherrier, J., Grulke, N.E., Jennings, V., Pincetl, Stephanie, Pouyat, R.V., Whitlow, T.H., Zipperer, W.C., 2011. Coupling biogeochemical cycles in urban environments: ecosystem services, green solutions, and misconceptions. Front. Ecol. Environ. 9 (1), 27–36. http://dx.doi.org/10.1890/090220.

Peters, Debra P C, Pielke, Roger A, Bestelmeyer, Brandon T, Allen, Craig D, Munson-McGee, Stuart, et al., 2004. Cross-scale interactions, nonlinearities, and forecasting catastrophic events. Proc. Nat. Acad. Sci. U.S.A. 101 (42), 15130–15135.

Pickett, S.T.A., Cadenasso, M.L., Grove, J.M., 2004. Resilience cities: meaning, models, and metaphors for integrating the ecological, socio-economic, and planning realms. Landscape Urban Plann. 69, 369–384.

Pickett, S.T.A., Cadenasso, M.L., Grove, J.M., Boone, C.G., Groffman, P.M., Irwin, E., Kaushal, S.S., Marshall, V., McGrath, B.P., Nilon, C.H., Pouyat, R. V, Szlavecz, K., Troy, A., Warren, P., 2011. Urban ecological systems: scientific foundations and a decade of progress. J. Environ. Manage. 92 (331–62).

PlaNYC. 2013. PlaNYC: A Stronger, More Resilience New York. The City of New York, New York, NY. Accessed on 03-21-2014 ⟨http://nytelecom.vo.llnwd.net/o15/agencies/sirr/SIRR_singles_Hi_res.pdf⟩.

Redman, C., 2014. Should sustainability and resilience be combined or remain distinct pursuits? Ecol. Soc. 19 (2), 37.

Rosenzweig, C., Solecki, W., 2010. Climate Change Adaptation in New York City: Building a Risk Management Response. New York Academy of Sciences, New York.

Rosenzweig, C., Solecki, W., Hammer, S.A., Mehrotra, S., 2010. Cities lead the way in climate-change action. Nature 467, 909–911.

Rosenzweig, C., Solecki, W.D., Hammer, S.A., Mehrotra, S. (Eds.), 2011. Climate Change and Cities: First Assessment Report of the Urban Climate Change Research Network. Cambridge University Press.

Sander, H., Polasky, S., Haight, R.G., 2010. The value of urban tree cover: a hedonic property price model in Ramsey and Dakota Counties, Minnesota, USA. Ecol. Econ. 69 (8), 1646–1656.

Scarlett, L., Boyd, J., 2013. Ecosystem services and resource management: institutional issues, challenges, and opportunities in the public sector. Ecol. Econ. (in press), 10.1016/j.ecolecon.2013.09.013.

Schewenius, M., McPhearson, T., Elmqvist., T., 2014. Opportunities for increasing resilience and sustainability of urban social–ecological systems: insights from the URBES and the Cities Biodiversity Outlook Projects. AMBIO 43, 434–444. http://dx.doi.org/10.1007/s13280-014-0505-z (Special Issue).

Seto, K.C., Reenberg, A., Boone, C.G., Fragkias, M., Haase, D., Langanke, T., Marcotullio, P., Munroe, D.K., et al., 2012. Urban land teleconnections and sustainability. Proc. Nat. Acad. Sci. U.S.A. 109, 7687–7692. http://dx.doi.org/10.1073/pnas.1117622109.

Solecki, W., Marcotullio, P., 2013. Climate change and urban biodiversity vulnerability. In: Elmqvist, T., et al. (Eds.), Cities and Biodiversity Outlook: Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities. Springer, Netherlands, pp. 85–504. http://dx.doi.org/10.1007/978-94-007-7088-1_25.

Solecki, W., Leichenko, R., O'Brien, K., 2011. Climate change adaptation strategies and disaster risk reduction in cities: connections, contentions, and synergies. Curr. Opin. Environ. Sustainability 3, 135–141.

Slavin, M., 2011. The Triple Bottom Line: Sustainability Principles, Practice, and Perspective in America's Cities. Island Press, Washington, D.C.

TEEB, 2011. The economics of ecosystem and biodiversity: TEEB manual for cities: ecosystem services in urban management, Ecosystem Services in Urban Management. UNEP, The European Union.

Tidball, K.G., Stedman., R., 2013. Positive dependency and virtuous cycles: from resource dependence to resilience in urban social–ecological systems. Ecol. Econ. 86, 292–299. http://dx.doi.org/10.1016/j.ecolecon.2012.10.004.

Troy, A., Grove, J.M., 2008. Property values, parks, and crime: a hedonic analysis in Baltimore, MD. Landscape Urban Plann. 87 (3), 233–245.

Walker, B., Holling, C.S., Carpenter, S.R., Kinzig, A., 2004. Resilience, adaptability and transformability in social–ecological systems. Ecol. Soc. 9 (2), 5.

Wilkinson, C., Sendstad, M., Parnell, S., Schewenius, M., 2013. Urban governance of biodiversity and ecosystem services. In: Elmqvist, T., Fragkias, M., Goodness, J., Güneralp, B., Marcotullio, P.J., McDonald, R.I., Wilkinson, C. (Eds.), Urbanization, Biodiversity and Ecosystem Services—Challenges and Opportunities. Dordrecht: Springer, Netherlands, pp. 539–587. http://dx.doi.org/10.1007/978-94-007-7088-1.

Yachi, S., Loreau, M., 1999. Biodiversity and ecosystem productivity in a fluctuating environment: the insurance hypothesis. Proc. Nat. Acad. Sci. U.S.A. 96, 1463–1468. http://dx.doi.org/10.1073/pnas.96.4.1463.