THE MOST IMPORTANT CURRENT RESEARCH QUESTIONS IN URBAN ECOSYSTEM SERVICES

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I. Introduction: The Importance of Urban Ecosystem Services

Nature is important to cities, not only for environmental protection but also for economic productivity, fiscal soundness, community life, and governance. We tend to take nature's ecological systems – or ecosystems – for granted, but they provide critically valuable services to society and to urban areas. Ecosystems help to control natural hazards and climatic threats, such as storm surges and floods, temperature variation, and wind. Ecosystems provide clean water by filtering out pollutants from stormwater runoff, streams and rivers, aquifers, and drinking water supplies. They provide refuge and reproduction habitat for plants and animals, facilitating biodiversity. They create a sense of place and recreational opportunities, contributing to quality of life by enhancing human physical and psychological health. They facilitate food production and local food economies. Well-functioning ecosystems not only are better able themselves to adapt to disturbances but they also strengthen the resilience and adaptive capacity of human communities and cities to disturbances and catastrophes.

Economists, ecologists, landscape planners, and legal and policy scholars often use the umbrella term "ecosystem services" to refer to the wide range of values and benefits provided by nature. City officials and the public often refer to specific urban ecosystem services with terms such as green infrastructure, low impact development, parks, stormwater best management practices (BMPs), urban trees and forests, watershed management and conservation, wetlands, agricultural lands and soils, and others. Regardless of the different terms, the constant factor is that communities rely heavily, indeed fundamentally, on nature for the continuing benefit from such services.[1] As Gretchen Daily has observed, "Unless humanity is suicidal, it should want to preserve, at the minimum, the natural life-support systems and processes required to sustain its own existence... This is not an academic issue but a matter of social choice today in the context of humanity's cultural heritage."[2]

This is particularly true for cities, where economic productivity, fiscal soundness, community life, and governance are tied to natural surroundings in distinct, unique and generally under-appreciated ways. Because the urbanized world depends on ecosystem services – both inside and outside of city boundaries – investing in the provision of ecosystem services will often be more cost-effective than response actions, such as treatment, restoration, and disaster response. For example, a city's use of green infrastructure to control and manage stormwater runoff often outperforms conventional "grey infrastructure" such as

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[1] Because different disciplines favor different terms to express the role of natural features providing service benefits, we use the terms "urban ecosystem services" and "green infrastructure" in this article depending on the disciplinary context.

[2] GRETCHEN C. DAILY, ED., NATURE'S SERVICES: SOCIETAL DEPENDENCE ON NATURAL ECOSYSTEMS 365 (1997).

pipes, channels, and treatment facilities. Natural systems can help reduce the impact of hurricanes, floods, and droughts by storing storm water and providing natural floodplains or reservoirs and storm breaks in coastal areas.

Given the importance of urban ecosystem benefits to surrounding populations, we might expect that ecosystem services would play a prominent role in the formulation of urban policies, plans, and laws. However, with rare exception, they do not. To be sure, some cities sustain critical watershed protection lands set aside a century ago; some are pursuing policies to provide and protect ecosystem services and green infrastructure. Many cities, though, are experiencing declines of the ecosystems that sustain them. Across the country, we see degradation and destruction of natural features in our urban environments, as well as inefficient allocations of land uses and development. Metropolitan areas are losing open space, farmland, and environmentally sensitive lands.

In some cases, this is driven by existing legal frameworks that favor property rights or a strong loyalty to Euclidean zoning preferences, in others by a bias to invest capital in grey infrastructure, the frequently occurring mismatched scales between ecosystem functions and governance structures, or other drivers. The net result is preference for the built rather than the natural environment. To be sure, sometimes this is perfectly appropriate and cost-effective; yet, in many cases investing in natural systems can provide services to urban communities for less expense than traditional built approaches and with significant additional public benefits.

Even where cities provide natural features and benefits, they may provide them inequitably and inefficiently. For example, low-income and minority communities often have received a disproportionately smaller allocation of park resources, stormwater control features, and other green infrastructure features. In part, space limitations in urban areas have obstructed the development of diverse urban forests. Politically, residents of more affluent, suburban areas have been more apt to demand tree plantings and maintenance than urban dwellers, and in any event, city officials often lack sufficient information about environmental benefits and ecosystem functions for effective use in urban planning decisions.

Moreover, there are mismatched scales between the services about which people care and the governance structures with the authority to manage the natural capital that provides these services. Even where the geographic scale is right, responsibilities for management and policy decisions fall into separate agency or professional/disciplinary silos that ignore the interrelationships among their governance or management functions in an interconnected environment. There are often legal uncertainties about how to implement policies, and whether local officials have the necessary authority to use certain governance or management tools. In sum, our cities are less livable, less economically vibrant, less ecologically and humanly healthy, and less socially just than they could be.

As America, and indeed the rest of the world, becomes increasingly urbanized, these issues are of the first importance in seeking to improve quality of life. The scholarship in the area, though, has been fragmented by discipline. Some scholars are increasingly studying the relationships between urban governance (including law and urban planning) and ecosystem services. Others have developed assessment, decision making, implementation, and even structural tools that can aid cities to provide and protect ecosystem services.[3] However, this literature remains nascent. Much remains to be done. First and foremost, we must identify the pressing research needs.

[3] Much of the initial research has been found in the gray literature supported by the efforts of city governments and non-governmental organizations. *See, e.g.*, NY City Green Infrastructure plan, http://www.nyc.gov/html/dep/html/stormwater/nyc_green_infrastructure_plan.shtml or the American Rivers series

This article brings together the collective insights of scholars and practitioners from a wide range of disciplines – lawyers and urban planners to ecologists and economists. Taking a comprehensive and wide-ranging view of the field, we identify the most important research questions that should shape the future of scholarship on urban ecosystem services. In doing so, we seek to help shape the trajectory of research across multiple disciplines in this growing and critical area.

Section II of the article provides a literature review, identifying the key publications to date and setting out gaps in the legal literature. In Section III, we explore three major categories of research – 1) equitable provision of ecosystem services in urban settings; 2) who pays for ecosystem services and how they pay; and 3) governance structure and institutions. For each of these, we explain what is known, what we need to know, and the proper framing of relevant research questions. Section IV concludes.

II. The State of the Literature on Urban Ecosystem Services and Governance

The literature on urban ecosystem services, law, and urban policy is growing but remains patchy and incomplete. The field continues to build on economic and ecological studies establishing benefits of ecosystems to society in general,[4] urban-specific research regarding the benefits of ecosystem services,[5] and the benefits of specific ecosystems, such as watershed lands[6] and urban forests.[7] In many cases, research is applicable to ecosystems located within urban areas and also to regionally-significant ecosystems that serve urban areas, such as regional farmland and soils that provide locally-grown food supplies to cities.[8] In the legal arena, much of the pathbreaking work on ecosystem services and law has

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of reports, http://www.americanrivers.org/newsroom/resources/going-green-to-save-green-economic-benefits-of-green-infrastructure-practices/

[4] *See, e.g.,* GRETCHEN C. DAILY, ED., NATURE'S SERVICES: SOCIETAL DEPENDENCE ON NATURAL ECOSYSTEMS (1997); Robert Costanza et al., *The Value of the World's Ecosystem Services and Natural Capital*, 387 NATURE 253 (1997); Robert Costanza and Herman E. Daly, *Natural Capital and Sustainable Development*, 6 CONSERVATION BIOLOGY 37 (1992).

[5] *See, e.g.,* Per Bolund & Sven Humhammar, *Ecosystem Services in Urban Areas*, 29 ECOLOGICAL ECONOMICS 293 (1999); Jὺrgen Brueste et al., *Urban Landscapes and Ecosystem Services*, in STEVE WRATTEN ET AL., EDS., ECOSYSTEM SERVICES IN AGRICULTURAL AND URBAN LANDSCAPES 83-104 (2013); Thomas Elmqvist et al. Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities. A Global Assessment. 2013 (Book)
http://link.springer.com/book/10.1007/978-94-007-7088-1.

[6] Travis Greenwalt & Deborah McGrath, *Protecting the City's Water: Designing a Payment for Ecosystem Services Program*, 24 NATURAL RESOURCES & ENV'T (2009).

[7] MARGARET M. CARREIRO ET AL., ECOLOGY, PLANNING, AND MANAGEMENT OF URBAN FORESTS: INTERNATIONAL PERSPECTIVES (2008); American Forests, *Urban Ecosystem Analysis Miami-Dade County UDB and the City of Miami, Florida* (2008); C.Y Jim & Wendy Y. Chen, *Ecosystem Services and Valuation of Urban Forests in China*, 26 CITIES 187 (2009); Cynnamon Dobbs et al., *A Framework for Developing Urban Ecosystem Forest Services and Goods Indicators*, 99 LANDSCAPE & URBAN PLANNING 196 (2011); Francisco J. Escobedo et al., *Urban Forests and Pollution Mitigation: Analyzing Ecosystem Services and Disservices*, 159 ENVTL. POLLUTION 2078 (2011) Francesc Baro et al. 2014. Contribution of Ecosystem Services to Air Quality and Climate Change Mitigation Policies: The Case of Urban Forests in Barcelona, Spain. AMBIO.
http://download.springer.com/static/pdf/702/art%253A10.1007%252Fs13280-014-0507-x.pdf?auth66=1403698470_bf163f01d73e65c29e6f297d42dc787b&ext=.pdf.

[8] Harpinder Sandhu & Steve Wratten, *Ecosystem Services in Farmland and Cities*, in WRATTEN ET AL, *supra* note 2, at 1, 10-11; Daniel La Rosa & Riccardo Privitera, *Characterization of Non-Urbanized Areas for Land-Use Planning of Agricultural and Green Infrastructure in Urban Contexts*, 109 LANDSCAPE & URBAN PLANNING 94 (2013).

occurred in the context of federal environmental law and state common-law property doctrines, such as nuisance and the public trust doctrine.[9]

A number of seminal publications, such as *The Law and Policy of Ecosystem Services*,[10] *Markets for Nature*,[11] and *Creating Markets for Ecosystem Services*[12] provided in-depth analyses of legal regimes and provision of ecosystem services. The role of urban legal systems in regulating, protecting, and valuing ecosystem services is less well understood. The ground in this area was broken in 2001 with the *Stanford Environmental Law Journal* article "Protecting Natural Capital through Ecosystem Services Districts."[13] Geoff Heal, Jim Salzman, Gretchen Daily and others provided an overview of ecosystem services and the issues involved in designing laws and institutions for ecosystem services, while contemplating the ways in which existing legal regimes act as barriers for effective ecosystem governance. "Protecting Natural Capital" and other articles in the same issue of the *Stanford Environmental Law Journal* for the first time identified the relevant laws and policies promoting the range of ecosystem services.[14]

The 2007 article, "The Structure of the Land Use Regulatory System," provided a second systematic example of how legal scholars have addressed the role of ecosystem services in urban planning and governance.[15] Tony Arnold explored the structural opportunities for and barriers to local governments incorporating ecosystem services protections into their land use planning and regulatory activities.[16] The article demonstrated how cities are increasingly using a wide variety of land-use planning and regulatory tools to conserve ecosystems and capture the services ecosystems provide to society, with a focus on watershed planning and governance as an adaptive and promising means for local government integration of ecosystem services policies into local planning and law.[17]

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[9] James Salzman, *Valuing Ecosystem Services*, 24 ECOLOGY L.Q. 887 (1997); James Salzman, et al., *Protecting Ecosystem Services: Science, Economics, and Law*, 20 STAN. ENVTL. L.J. 309 (2001); J.B. Ruhl & R. Juge Gregg, *Integrating Ecosystem Services Into Environmental Law: A Case Study of Wetlands Mitigation Banking*, 20 STAN. ENVTL. L.J. 365 (2001); James Salzman, *A Field of Green? The Past and Future of Ecosystem Services*, 21 J. LAND USE & ENVTL. L. 133 (2006); J.B. Ruhl & James Salzman, *Ecosystem Services and the Public Trust Doctrine: Working Change from Within*, 15 SOUTHEASTERN ENVTL. L.J. 223 (2006); J.B. Ruhl & James Salzman, *The Law and Policy Beginnings of Ecosystem Services*, 22 J. LAND USE & ENVTL. L. 157 (2007); J.B. Ruhl, *The "Background Principles" of Natural Capital and Ecosystem Services - Did Lucas Open Pandora's Box?,* 22 J. LAND USE & ENVTL. L. 525 (2007) J.B. Ruhl, *Making Nuisance Ecological*, 58 CASE W. RES. L. REV. 753 (2008); J.B. Ruhl, *Agriculture and Ecosystem Services: Strategies for State and Local Governments*, 17 N.Y.U. ENVTL. L.J. 424 (2008).

[10] J.B. RUHL ET AL., THE LAW AND POLICY OF ECOSYSTEM SERVICES (2007).

[11] Barton Thompson, Jr., *Markets for Nature*, 25 WILLIAM & MARY ENVTL. L. & POL'Y REV. 261 (2000).

[12] James Salzman, *Creating Markets for Ecosystem Services: Notes from the Field*, 80 N.Y.U. L. REV. 870 (2005).

[13] Geoffrey Heal et al., *Protecting Natural Capital through Ecosystem Service Districts*, 20 STAN. ENVTL. L.J. 333 (2001).

[14] List of articles

[15] Craig Anthony (Tony) Arnold, *The Structure of the Land Use Regulatory System in the United States*, 22(2) J. LAND USE & ENVTL. L. 441 (2007)

[16]. *Id.*

[17] *Id. See also* CRAIG ANTHONY (TONY) ARNOLD ET AL., KENTUCKY WET GROWTH TOOLS FOR SUSTAINABLE DEVELOPMENT: A HANDBOOK ON LAND USE AND WATER FOR KENTUCKY COMMUNITIES (2009); Craig Anthony (Tony) Arnold, *Clean-Water Land Use: Connecting Scale and Function*, 23 PACE ENVTL. L. REV. 291 (2006); Craig Anthony (Tony) Arnold, *For the Sake of Water: Land Conservation and Watershed Protection*, 14 SUSTAIN: A J. OF ENVTL. & SUSTAINABILITY ISSUES 16 (2006); Craig Anthony (Tony) Arnold, *Adaptive Watershed Planning and Climate Change*, 5 ENVTL. & ENERGY L. & POL'Y J. 417 (2010); Craig Anthony (Tony) Arnold, *Fourth-Generation Environmental Law: Integrationist and Multimodal*, 35 WM & MARY ENVTL. L. & POL'Y REV. 771 (2011)..

The 2011 article, "Sustaining Ecosystem Services through Local Environmental Law," tackled the extent to which local law and governance can sustain the socially and economically valuable services that ecosystems provide to human communities.[18] Keith Hirokawa linked the literature on the law of ecosystem services with local environmental law, conceiving local ecosystem services protection as a matter of local governance that uses the whole range of legal and policy tools available to localities, not just land use planning and regulation. The article presented detailed examples of local laws that protect ecosystem functionality.[19]

In the urban planning, context, scholars have begun to develop a body of literature addressing the importance of ecosystem functions to land use planning, albeit not always by explicitly addressing ecosystem services. Under the guise of planning principles for the "ecological city" or the "biophilic city," this literature is exploring the benefits of ecosystems to urban development.[20] The "Smart Growth" urban planning literature gives some effective attention to ecosystem services by emphasizing the value of open space and farmland preservation[21] but less attention to other aspects of ecosystem services, such as water and watersheds,[22] or how high-density development could adversely affect urban ecosystem functions.[23]

The most intentional and extensive work incorporating ecosystem services into urban planning focuses on the social, economic, and environmental benefits of "green infrastructure."[24] The term "green infrastructure" has been used broadly to encompass natural systems and features that have been protected from alteration, restored natural systems and features, and humanly created or engineered bio-physical

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[18] Keith H. Hirokawa, *Sustaining Ecosystem Services through Local Environmental Law*, 28 PACE ENVTL. L. REV. 760 (2011).

[19] Hirokawa has also written a series of articles examining the role of law and local governance in providing and protecting specific ecosystem services from urban forests, watersheds, wetlands, climate, and species' habitat. *See, e.g.*, Keith H. Hirokawa, *Sustainability and the Urban Forest: An Ecosystem Services Perspective*, 51 NATURAL RESOURCES J. 233 (2012); Keith H. Hirokawa, *Driving Local Governments to Watershed Governance*, 42 ENVTL. L. 157 (2012); Keith Hirokawa, *Disasters and Ecosystem Services Deprivation: From Cuyahoga to the Deepwater Horizon*, 74 ALBANY L. REV. 543 (2011); Keith H. Hirokawa, *Local Planning to Preserve Wetlands Assets: Community,Baselines, and Ecosystem Services*, in KIMBERLY CONNOLLY, ED. , BEYOND RAPANOS: THE NEXT GENERATION OF WETLAND REGULATION (forthcoming 2014).

[20] Some of the most important works include TIMOTHY BEATLEY & KRISTY MANNING, THE ECOLOGY OF PLACE: PLANNING FOR ENVIRONMENT, ECONOMY, AND COMMUNITY (1997); JOHN RANDOLPH, ENVIRONMENTAL LAND USE PLANNING AND MANAGEMENT (2004); STEPHEN R. KELLERT, BUILDING FOR LIFE: DESIGNING AND UNDERSTANDING THE HUMAN-NATURE CONNECTION (2005); RANDOLPH T. HESTER, DESIGN FOR ECOLOGICAL DEMOCRACY (2006); IAN L. MCHARG, THE ESSENTIAL IAN MCHARG: WRITINGS ON DESIGN AND NATURE (2006); TIMOTHY BEATLEY, BIOPHILIC CITIES: INTEGRATING NATURE INTO URBAN DESIGN AND PLANNING (2011).

[21] Smart Growth Network, *Principles of Smart Growth* (2010); David N. Bengston et al., *Public Policies for Managing Urban Growth and Protecting Open Space: Policy Instruments and Lessons Learned in the United States*, 69 LANDSCAPE & URBAN PLANNING 271 (2004).

[22] Craig Anthony (Tony) Arnold, *Is Wet Growth Smarter Than Smart Growth?: The Fragmentation and Integration of Land Use and Water*, 35 ENVTL. L. REP. 10152 (2005). The "wet growth" literature developed at least partly in response to the "smart growth" literature's insufficient attention to water and watersheds.

[23] Jamie Tratalos et al., *Urban Form, Biodiversity Potential, and Ecosystem Services*, 83 LANDSCAPE & URBAN PLANNING 308 (2007).

[24] *See, e.g.*, MARK A. BENEDICT & EDWARD T. MCMAHON, GREEN INFRASTRUCTURE: LINKING LANDSCAPES AND COMMUNITIES (2006); Konstantinos Tzoulas et al., *Promoting Ecosystem and Human Health in Urban Areas Using Green Infrastructure: A Literature Review*, 81 LANDSCAPE & URBAN PLANNING 167 (2007); Robert F. Young & E. Gregory McPherson, *Governing Metropolitan Green Infrastructure in the United States*, 109 LANDSCAPE & URBAN PLANNING 67 (2013). A recent American Planning Association Planning Advisory Service Report focuses on green infrastructure. DAVID ROUSE & IGNACIO BUNSTER-OSSA, GREEN INFRASTRUCTURE: A LANDSCAPE APPROACH (2013).

systems and features. The term is used most often to refer to increasingly favored techniques, technologies, and management approaches to reduce or manage stormwater runoff without relying primarily or solely on traditional pipe and concrete "grey infrastructure."[25] The City of Philadelphia, for example, is often praised for its comprehensive, long-term, and innovative green-infrastructure program to control runoff and protect water quality.[26] However, green infrastructure is much broader than rain gardens and bioswales, and provides many more benefits than stormwater runoff control. For example, urban trees help not only to control runoff but also to moderate temperatures, contribute to psychological health, minimize soil erosion, sequester carbon, reduce energy costs, enhance the walkability of the streetscape, support urban biodiversity, and provide aesthetic beauty.[27] Green infrastructure now plays an important role in urban planning principles.[28]

Researchers have also developed a significant number of assessment and/or decisional tools to aid urban officials in valuing and protecting ecosystem services.[29] As with other areas of environmental and land-use decision making, there remains concern about the accuracy or utility of these tools.[30] Recent scholarship follows the "no-panaceas" approach of scholars who study complex environmental-social dynamics,[31] recommending a toolbox or multimodal approach over an optimal policy design approach.[32] This pluralistic approach matches a policy context in which many different values are important, where various ecosystem services might have to be traded off against one another, yet the complexity of interconnected systems elevates the risk that any single policy choice will suddenly and unexpectedly fail due to unanticipated disturbances and responses.[33] In this setting, social-ecological resilience and the

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[25] U.S. Environmental Protection Agency, *What Is Green Infrastructure?* (2011).

[26] *See* Philadelphia Water Department's Green Cities, Clean Water plan and program at http://www.phillywatersheds.org/what_were_doing/documents_and_data/cso_long_term_control_plan.

[27] *See* note 4, *supra*.

[28] Green infrastructure is not an entirely new principle in urban planning. *See* Theodore Eisenman, *Frederick Law Olmsted, Green Infrastructure, and the Evolving City*, 12 J. PLANNING HISTORY 287 (2013).

[29] *See, e.g.*, PETER KAREIVA ET AL. EDS., NATURAL CAPITAL: THEORY AND PRACTICE OF MAPPING ECOSYSTEM SERVICES (2011); TEEB – THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY., TEEB MANUAL FOR CITIES: ECOSYSTEM SERVICES IN URBAN MANAGEMENT (2011); Erik Andersson, *Urban Landscapes and Sustainable Cities*, 11 ECOLOGY & SOCIETY 34 (2006); Rudolf de Groot, *Function-Analysis and Valuation as a Tool to Assess Land Use Conflicts in Planning for Sustainable, Multi-Function Landscapes*, 75 LANDSCAPE & URBAN PLANNING 175 (2006); Benjamin Burkhard et al*., Landscapes' Capacities to Provide Ecosystem Services – A Cancept for Land-Cover Based Assessments*, 15 LANDSCAPE ONLINE 1 (2009); Gretchen C. Daily et al., *Ecosystem Services in Decision Making: Time to Deliver*, 7 FRONTIERS IN ECOL. & ENV'T 21 (2009). For tools to evaluate the ecosystem services of urban trees and make tree canopy planning decision, see the sources cited in note 4, *supra*. For an overview of tools to evaluate the value of watershed protections of a city's water supply, see Greenwalt and McGrath, *supra* note 3

[30] One researcher makes a compelling case for the integration of ecosystem services into urban planning, but asserts that too little planning-relevant information is known about urban ecosystem services. Jari Niemelä,et al., *Using the Ecosystem Services Approach for Better Planning and Conservation of Urban Green Spaces: a Finland Case Study* 19 BIODIVERSITY & CONSERVATION 3225 (2010).

[31] Elinor Ostrom et al., *Going Beyond Panaceas*, 104 PROC. NAT'L ACAD. SCI. USA 15176 (2007).

[32] *See, e.g.*, Daily et al, *supra* note 29;TEEB, *supra* note 32; Craig Anthony (Tony) Arnold, *Fourth-Generation Environmental Law: Integrationist and Multimodal*, 35 WM & MARY ENVTL. L. & POL'Y REV. 771 (2011); CRAIG ANTHONY (TONY) ARNOLD ET AL., KENTUCKY WET GROWTH TOOLS FOR SUSTAINABLE DEVELOPMENT: A HANDBOOK ON LAND USE AND WATER FOR KENTUCKY COMMUNITIES (2009). For broader toolbox approaches to ecosystem services generally, see JANET RANGANATHAN ET AL., BANKING ON NATURE'S ASSETS: HOW MULTILATERAL DEVELOPMENT BANKS CAN STRENGTHEN DEVLEOPMENT BY USING ECOSYSTEM SERVICES (2009) (note: Table 5 at pp. 20-22 is an especially helpful visual of different tools), and James Salzman, *Designing Payments for Ecosystem Servivces*, PERC Policy Series Report No. 48 (2010).

[33] Guilia Wegner & Unai Pascual, *Cost-Benefit Analysis in the Context of Ecosystem Services for Human Well-Being: A Multidisciplinary Critique*, Ecosystem Services Economics Working Paper Series Paper No. 13, United Nations Environment Programme (2011); Adrienne Grêt-Regamey et al., *Understanding Ecosystem Services Trade-*

adaptive capacity of institutions become particularly important.[34] Hence the urban ecosystem services literature is beginning to link the literatures on resilient cities, social-ecological resilience, adaptive governance, adaptive management, and adaptive planning.[35]

In sum, the role of ecosystem services in urban settings has been attracting increasing interest but has not yet matured to the point where one can speak meaningfully of the field of "urban ecosystem services."

III. Promising Research Areas

This section explores in detail the three broad research areas of urban ecosystem services. Part A considers the distributional impacts of service provision and the challenges posed by the pursuit of environmental equity. Part B turns to financing questions. While attractive in theory, providing urban ecosystem services on the ground requires effective funding mechanisms that work across jurisdictions, government silos, and private and public ownership. These raise very real concerns over who pays, who is paid, and the constraints created by legal requirements and inertia of the status quo. Part C considers issues of governance, examining the institutional challenges in providing services meaningfully in the urban landscape. In each part, we explain the basic issues and then identify particularly promising research questions.

A. Equitable Provision of Urban Ecosystem Services

One of the central questions for urban ecosystem services is how these services can be provided in both an environmentally beneficial and socially equitable manner. Environmental inequality occurs when certain sectors of the population—predominantly low-income and minority populations—either bear a disproportionate burden from industrial pollution sources or receive fewer of the benefits from

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Offs with Interactive Procedural Modeling for Sustainable Urban Planning, 109 LANDSCAPE & URBAN PLANNING 107 (2013); Jari Lyytimäki et al., *Nature as a Nuisance: Ecosystem Services and Disservices to Urban Lifestyle*, 5 ENVTL. SCI. 161 (2008). *See also* sources cited in notes 34-35, *infra*.

[34] *See, e.g.*, Jon Paul Rodriguez et al, *Trade-offs across Space, Time, and Ecosystem Services*, 11 ECOLOGY & SOCIETY 28 (2006); Garry D. Peterson et al., *Assessing Future Ecosystem Services: A Case Study of the Northern Highlands Lake District, Wisconsin*, 7 CONSERVATION ECOL. 1 (2003).

[35] *See, e.g.*, Craig Anthony (Tony) Arnold, *Resilient Cities and Adaptive Law*, 50 ID. L. REV. ___ (forthcoming 2014), and the Beijer Institute of Ecological Economics Project SUPER: Sustainable Urban Planning for Ecosystem Services and Resilience, http://www.beijer.kva.se/research_under.php?id=30, led by Johan Colding. Some of the key works on resilience that are relevant to urban ecosystems include LANCE H. GUNDERSON & C.S. HOLLING, PANARCHY: UNDERSTANDING TRANSFORMATIONS IN HUMAN AND NATURAL SYSTEMS (2002); BRIAN WALKER & DAVID SALT, RESILIENCE THINKING: SUSTAINING ECOSYSTEMS AND PEOPLE IN A CHANGING WORLD (2006); BRIAN WALKER & DAVID SALT, RESILIENCE PRACTICE:BUILDING CAPACITY TO ABSORB DISTURBANCE AND MAINTAIN FUNCTION (2012); BRUCE EVAN GOLDSTEIN, ED., COLLABORATIVE RESILIENCE: MOVING THROUGH CRISIS TO OPPORTUNITY (2012). Numerous organizations focus on enhancing the resilience and adaptive capacity of cities. Among these are ICLEI (http://resilient-cities.iclei.org/), the Rockefeller Foundation (http://100resilientcities.rockefellerfoundation.org/), the Center for Resilient Cities (http://www.resilientcities.org/Resilient_Cities/PROFILE.html), the United Nations Office for Disaster Risk Reduction (http://www.unisdr.org/campaign/resilientcities), Next City (http://nextcity.org/resilientcities), the International Federation for Housing and Planning (http://www.ifhp.org/content/climate-resilient-cities#.Uu5kL0ko6tU), Ceres (http://www.ceres.org/resources/reports/building-resilient-cities-from-risk-assessment-to-redevelopment), and Biophilic Cities (http://biophiliccities.org/). Some resilient-cities scholarship or activities, though, focus primarily on disaster preparedness and risk reduction, or on climate change. *See, e.g.*, PETER NEWMAN ET AL., RESILIENT CITIES: RESPONDING TO PEAK OIL AND CLIMATE CHANGE (2009).

environmentally beneficial projects. Environmental justice is "the principle that all people and communities are entitled to equal protection of environmental and public health laws."[36]

Since the 1980s, a robust literature has examined the distributional and social justice impacts from environmental hazards and burdens, including health disparities in the population that are exacerbated by the built environment, to social science research focused on the causes of environmental inequality and legal scholarship focused on how to alleviate it.[37] Research considering the equitable provision of ecosystem services has been far less common.[38] The paragraphs below identify the key research findings to date.

Environmental Equity and Urban Forest Cover.

Research at the urban level often focuses on urban forest issues. Perkins et al. examine the outcomes of a municipal tree planting program in Milwaukee and find that programs promoting private participation in tree planting can create inequalities because lower-income neighborhoods with primarily renter-occupied housing may not participate in tree planting programs.[39] Heynen et al. examines the overall distribution of trees in the Milwaukee area and finds disparities in urban tree cover that are attributable to housing dynamics, household income, and racial and ethnic factors.[40] Landry and Chakraborty find that in Tampa, FL, tree cover on public rights of way is significantly lower in neighborhoods with higher proportions of African-American, low-income, and non-home owner residents.[41] In a similar study, Flocks et al. find that in the Miami-Dade area predominantly white neighborhoods tend to have greater tree cover, canopy density, and tree species diversity as well as greater energy savings from urban tree cover.[42] They attribute the uneven distribution of urban tree cover to socioeconomic factors such as housing patterns, residential control over the physical environment, financial means, and pre-existing levels of environmental inequality due to the location of environmental hazards. As a result, neighborhoods in urban areas with little vegetation are more vulnerable to extreme heat events, making low income and minority residents more vulnerable to climate change.[43]

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[36] Bullard, R. D. *Dumping in Dixie: Race, Class, and Environmental Quality* 493 (3 ed. 2000).

[37] *See, e.g.,* Srinivasan, Shoba, Liam R. O'Fallon, and Allen Dearry. Creating Healthy Communities, Healthy Homes, Healthy People: Initiating a Research Agenda on the Built Environment and Public Health. American Journal of Public Health: September 2003, Vol. 93, No. 9, pp. 1446-1450.; Mohai and Bryant 1992 Mohai, P. and B. Bryant. 1992. "Environmental Racism: Reviewing the Evidence." Pp. 163-76 in *Race and the Incidence of Environmental Hazards*, edited by Bunyan Bryant and Paul Mohail. Boulder, CO: Westview.

[38] *See, e.g.,* THOMAS SIKOR, ED., THE JUSTICES AND INJUSTICES OF ECOSYSTEM SERVICES (2013); Joan Flocks et al., *Environmental Justice Implications of Urban Tree Cover in Miami-Dade County, Florida*, 4 ENVTL. JUSTICE 125 (2011);G. Darrel Jenrette et al., *Ecosystem Services and Urban Heat Riskscape Moderation: Water, Green Spaces, and Social Inequality in Phoenix, USA*, 21 ECOL. APPLICATIONS 2637 (2011); Henrik Ernstson, *The Social Production of Ecosystem Services: A Framework for Studying Environmental Justice and Ecological Complexity in Urbanized Landscapes*, 109 LANDSCAPE & URBAN PLANNING 7 (2013); Bill M. Jesdale et al., *The Racial/Ethnic Distribution of Heat Risk–Related Land Cover in Relation to Residential Segregation*, 121 ENVTL. HEALTH PERSPECTIVES 811 (2013).

[39] Perkins, H.A., N. Heynen, J. Wilson. 2004. "Inequitable access to urban reforestation: the impact of urban political economy on housing tenure and urban forests." *Cities* 21: 291-299.

[40] Heynen, N., H.A. Perkins, and P. Roy. 2006. "The Political Ecology of Uneven Urban Green Space: The Impact of Political Economy Producing Environmental Inequality in Milwaukee." *Urban Affairs Review* 42: 3-25.

[41] Landry, S. and J. Chakraborty. 2009. "Street trees and equity: evaluating the spatial distribution of an urban amenity." *Environment and Planning* 41: 2651-2670.

[42] Flocks, J., F. Escobedo, J. Wade, S. Varela, and C. Wald. 2011. "Environmental Justice Implications of Urban Tree Cover in Miami-Dade County, Florida." *Environmental Justice* 4: 125-134.

[43] Jenerette, G.D., S.L. Harlan, W.L. Stefanov, and C.A. Martin 2011. "Ecosystem services and urban heat riskscape moderation: water, green spaces, and social inequality in Phoenix, USA." *Ecological Applications* 21: 2637–2651.

Environmental Equity and Greenspace/Park Access.

Other research focuses on the unequal access to urban parks and has been spearheaded by federal agencies in developing national strategies to alleviate environmental inequalities in park access. The National Park Service's recent *Healthy Parks, Healthy People Science Plan* compiles extensive evidence-based social science research that identifies "[r]elationships between socio-economic status and participation and access to green space and outdoor recreation."[44] For example, NPS reports that "[g]reen spaces and parks, which promote good health, can play an important role in alleviating socioeconomic health disparities."[45] The overriding concern of the report is that people of color and low income populations still face disparities regarding both health and access to parks, since "the communities with the least amount of access to parks and open space tend to have higher rates of childhood diseases related to obesity such as diabetes." According to NPS, for example, "36 percent of black and 35 percent of Hispanic high school students nationwide are overweight or obese, while 24 percent of non-Hispanic white high school students suffer from these conditions"[46]

Environmental Equity and Legal Frameworks.

A final area of focus for equity and urban ecosystem services research is the development of legal and policy strategies to address these distributional problems. Much of this work has evolved from the advocacy efforts of researchers such as the late Luke Cole and non-profit organizations such as The City Project, located in Los Angeles.[47]

There is scant environmental justice legislation, so advocates have been creative, relying on a wide range of laws. The first is the Clinton-era Executive Order 12898 on Environmental Justice, which requires each federal agency to "make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations."[48] Title VI of the Civil Rights Act of 1964 may also be applied to prevent minority communities and low-income communities from being subject to discriminatory effects. Title VI and its regulations also promote equity in ecosystem services by prohibiting recipients of federal financial assistance (including presumably all state, regional, and local park agencies) from discriminating based on race, color, or national origin in their programs or activities.[49] Finally, the Affordable Care Act provides protections

[44] National Park Service, 2013. *Healthy Parks, Healthy People Science Plan*.
[45] (Mitchell & Popham, 2008)." (38).
[46] National Park Service. 2013. *San Gabriel Watershed and Mountains Special Resource Study & Environmental Assessment* (Newsletter #5, Nov. 2011) (*San Gabriel Study*), p. 219.
[47] Cole, L. 1992. "Empowerment as the Key to Environmental Protection: The Need for Environmental Poverty Law." *Ecology Law Quarterly* 19:619-684. The City Project has conducted a number of influential studies of inequitable distribution of parks and other urban infrastructure in Southern California by race, ethnicity, and class, several of which have been used with legal, planning, and political strategies to address these disparities.
[48] Executive Order 12898 § 1-101 (Feb. 11, 1994); *see also id.*, §§ 1-102, 6-604. See also Executive Order 13045 (directing each federal agency to identify, assess, and address environmental health and safety risks that may disproportionately affect children).
[49] Section 601 of Title VI provides: "No person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance." 42 U.S.C. § 2000d. The Supreme Court held in the 2001 Alexander v. Sandoval case that there is no private right of action for disparate impact under Title VI. *Cite*. However, the DOJ interpreted the case to allow federal agencies to use their Title VI regulatory authority to prohibit actions having a disparate impact, and many did so. For departmental regulations adopting Title VI, *see, e.g.*, 43 C.F.R. § 17.1 et seq. (Department of Interior); 40 C.F.R. § 7.1 et seq. (EPA); 49 C.F.R. § 21.1 et seq. (Department of Transportation).

against health discrimination based on race, color, national origin, limited English language proficiency, immigration status, and other characteristics in Section 1557 that may enable advocacy focused on achieving greater access to park resources in disadvantaged communities.[50]

The City Project has developed a framework for using the Civil Rights Act of 1964 and its implementing regulations, the federal Executive Order 12898 on environmental justice and health, sections of the Affordable Care Act, and parallel state laws to advocate successfully for greater park access in Los Angeles County.[51] In other cities, grassroots advocates and government leaders or planners have relied on a variety of planning and legal tools in pursuing fairness and community health in urban ecosystem services policies.[52] The results may provide an empirical foundation for pursuing new and innovative research into the ways law can facilitate distributional equity.

The following questions identify the most pressing research issues concerning the equitable provision of ecosystem services in urban areas.

- How should cities incorporate environmental equity into their planning for ecosystem services?

- Should certain ecosystem services (e.g., parks and green space) be prioritized over others according to the preexisting levels of environmental inequality in a community?

- If certain ecosystem services are targeted based on the preexisting levels of inequality, how do cities and local governments decide which inequalities to address first? For example, does a city prioritize alleviating urban heat island effects in more vulnerable communities to allow those communities to better adapt to climate change? Alternatively, does the city prioritize providing green space and park access to communities?

- Often the natural infrastructure that supports targeted ecosystem services (e.g., increased storm water retention) will provide additional co-benefits (e.g., reduced local heat island effect, improved air quality, and expanded recreational opportunities). What policies could enhance choices that achieve greater environmental equity as well as other goals of urban communities?

Preventing unintended consequences

The provision of urban ecosystem services through green infrastructure often offers the positive externality of environmental amenities. When these environmental amenities are substantial enough to alter property values, some segments of the population (renters for example) may be priced out of the very same low-income and minority communities that the ecosystem services were originally intended to

[50] Section 1557 references prior laws that protect against health discrimination, including Title VI of the Civil Rights Act. The Act also includes physical activity, healthy land use, and infrastructure projects as part of its mandate. *See, e.g.*, ACA sections 4001, 4201, 4306; Texas Health Institute, *The Affordable Care Act & Racial and Ethnic Health Equity Series: Report No. 4 Public Health and Prevention Programs for Advancing Health Equity* at iii-xii, 33-34, 41-46, 48 (Nov. 2013); American Public Health Association, *Issue Brief: Prevention Provisions in the Affordable Care Act* at 6-9, 11, 18 (Oct. 2010).

[51] See, e.g., ROBERT GARCÍA & SETH STRONGIN, HEALTHY PARKS, SCHOOLS AND COMMUNITIES: MAPPING GREEN ACCESS AND EQUITY FOR SOUTHERN CALIFORNIa (2011); ROBERT GARCÍA & AUBREY WHITE, HEALTHY PARKS, SCHOOLS AND COMMUNITIES: MAPPING GREEN ACCESS AND EQUITY FOR THE LOS ANGELES REGION (2006); ROBERT GARCÍA ET AL., DREAMS OF FIELDS: SOCCER, COMMUNITY, AND EQUAL JUSTICE (2002). On The City Project's work, see http://www.cityprojectca.org/.

[52] An American Planning Association Planning Advisory Service Report addresses many of these issues and tools. CRAIG ANTHONY (TONY) ARNOLD, FAIR AND HEALTHY LAND USE: ENVIRONMENTAL JUSTICE AND PLANNING (2007).

help. Research is needed to better understand the dynamics of gentrification and displacement and how to ensure that the low-income and minority communities are able to stay in their neighborhoods to enjoy the benefits of ecosystem services.[53]

- What is the empirical evidence of green infrastructure or other projects that provide greater ecosystem services in the community leading to gentrification or displacement of disadvantaged communities?

- Are there policy mechanisms around the country that cities have used successfully to prevent gentrification and displacement following the introduction of environmental amenities?

- What authorities do cities need to prevent gentrification and displacement resulting from an expansion of ecosystem services in the community?

- Do cities have these necessary authorities in place and, if not, what would be required to adopt them?

B. Payments for Urban Ecosystem Services

Green infrastructure such as watershed protection areas and parks have traditionally been financed and maintained as part of city infrastructure supported by taxes, fees or public bond measures. However, many types of ecosystem services can only be provided on a meaningful scale if they take place across a mix of public and private lands. For example, effective green infrastructure programs to reduce runoff and stormwater flows require city-wide deployment of green rooftops, rain gardens, rain barrels, and permeable pavement, among other measures. This section explores some of the approaches government entities may use to fund ecosystem services directly and tools they can use to encourage private property owners to pay for the provision of such services in the urban environment, highlighting areas where additional research is needed.

The incorporation of ecosystem services into the urban landscape will generally require a change in land use practices or in the pattern and location of developed areas and the installation of physical assets to provide the desired benefits. As a result, an initial concern is whether the party receiving the ecosystem services should pay for the service itself or for the land use practices and physical assets that are required to provide the service, i.e., for the green infrastructure or the service provision. For example, if wetlands are created or restored to address water quality issues, the cost of the initial construction of the wetland can far exceed the ongoing maintenance costs that will be incurred once the wetland is established and providing ecosystem services.[54] In these cases, if the entity paying for ecosystem services is limited to paying for the services themselves, the payments offered may be insufficient to encourage

[53] Recent studies suggest that neighborhood gentrification does not always displace residents and can actually enhance their conditions. *See* Laura Sullivan, *Gentrification May Actually Be Boon To Longtime Residents*, NPR NEWS, Jan. 22, 2014 http://www.npr.org/2014/01/22/264528139/long-a-dirty-word-gentrification-may-be-losing-its-stigma. In other cases, though, the adverse effects of gentrification are clear. Further research is needed to understand the forces at work and how to advance urban ecosystem services without displacing area residents.

[54] Once installed, any physical assets may require ongoing maintenance to ensure that they continue to provide the desired ecosystem benefits. In fact, in a recent evaluation of green infrastructure projects funded under the American Recovery and Reinvestment Act, the EPA concluded that "proper maintenance is essential to maximizing the environmental, social, and economic benefits of green infrastructure, as well as ensuring that projects perform as they were designed to." EPA, The Importance of Operation and Maintenance for the Long-Term Success of Green Infrastructure 2 (), *available at* http://water.epa.gov/grants_funding/cwsrf/upload/Green-Infrastructure-OM-Report.pdf. *See* http://www.water.ncsu.edu/watershedss/info/wetlands/manage.html.

private landowners to provide the initial ecosystem service benefits. Without financing to address up front costs, fees collected may also be insufficient to support ecosystem services benefits from public or private infrastructure.

Co-benefits for private property owners can provide one strategy to make urban ecosystem service provision more attractive investments. For example, while a private property owner cannot prevent the public as a whole from benefitting from the storm water reduction benefits of his rain garden (as positive externalities), the property owner may obtain other aesthetic, recreational and property value benefits that offset his capital costs to provide the ecosystem service. Alternatively, cities might offer property owners reduced stormwater fees if their properties provide floodwater services.

While there have been several studies on the cost-effectiveness of green infrastructure to mitigate storm water impacts,[55] there is sparse literature on the long-term costs of maintaining these ecosystem services as well as the costs to install and maintain other natural infrastructure such as parks, urban trees, and stream buffers, to provide ecosystem services beyond storm water mitigation in the urban environment.

- Research on the costs of providing ecosystem services should focus on the costs of installing and maintaining the assets that provide ecosystem services and comparing these costs to the monetized benefits of ecosystem services (which can include the public's willingness to pay for the benefits) to determine whether potential payments for ecosystem services would be sufficient to cover the capital costs required to provide them.

- Research on the additional ecosystem service benefits provided by green infrastructure would be useful in assessing the level of stormwater surcharges that may be necessary to encourage property owners to implement green infrastructure measures to mitigate stormwater. Similarly, analysis to quantify the co-benefits of other natural infrastructure (e.g. street trees, green roofs, etc.) can help inform policies that support those structures.

Accounting also matters. The Government Accounting Standards Board (GASB)[56] uses traditional accounting for infrastructure, which does not allow for inclusion of the broader suite of benefits that green infrastructure provides.[57] As a result, the broader benefits green infrastructure can provide to the public and differences in maintenance approaches are not included in determining the value of these assets and thus can make it difficult for municipalities to consider these values in their decisions, whether that is for development of new green infrastructure, replacement of grey built infrastructure, or maintenance of existing assets. GASB has been exploring how a broader "ecosystem services" accounting method might work.[58]

- Research should support the efforts of GASB to explore the development of practical standards for green accounting that would recognize the costs and benefits of ecosystem services as assets.

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[55] *See, e.g.*, EPA, *supra* note 54; Jennifer Dill, et al., Demonstrating the Benefits of Green Streets for Active Aging: Final Report to EPA (2010); American Rivers et al., Banking on Green: A Look at How Green Infrastructure can Save Municipalities Money and Provide Economic Benefits Community-Wide.

[56] The Governmental Accounting Standards Board (GASB) sets standards of accounting and financial reporting for state and local governments in the United States. http://www.gasb.org/home

[57] *See* D. Cosman, et al., Spearheading Natural Capital Accounting: Water Utility Case Study, Solutions Journal 2:28-31 (2011), *available at* http://www.thesolutionsjournal.com/node/1018.

[58] ***See, e.g.,*** GASB, Technical Plan for The Final Third of 2013: Potential Projects, 2013, *available at* http://www.gasb.org/jsp/GASB/Page/GASBSectionPage&cid=1175804837162.

Public Funding of Ecosystem Services Projects

Municipalities, in particular, face limitations on the sources of funding that may be available to implement ecosystem services programs. Because many states and municipalities are unable to run budget deficits, any funding for ecosystem services must be backed by an accompanying revenue stream.[59] Thus the two primary mechanisms for public funds to support ecosystem services projects would be either allocating a portion of tax revenue to ecosystem services projects or issuing revenue bonds. While the authors are currently not aware of any legal restrictions that would broadly prevent the allocation of general tax revenues to ecosystem services projects, in the current climate of constrained municipal and state budgets, it is not likely that many governments will be able to allocate significant tax revenue to ecosystem services projects.

If states and municipalities turn to revenue bonds to fund ecosystem services projects, there are significant limitations on bonding authority that may impair their ability to obtain sufficient funding. For example, the Internal Revenue Code imposes limitations on the use of tax-exempt bonds to raise funds for projects that will occur on private property.[60] This limits the ability of cities to raise capital for activities like rain gardens, green roofs, and retention basin retrofits by private home and business owners. The Texas Constitution expressly prohibits the expenditure of public funds for the improvement of private property.[61]

- Research should review municipal bonding rules in the various states in order to understand the full extent of the limitations on the use of revenue bonds to fund green infrastructure projects as well as the additional costs involved if taxable bonds must be issued.

- Does public ownership of an easement avoid the Internal Revenue Code restrictions on the use of tax-exempt bonds for private property projects?

- If public financing is used to support projects on private property, research will be needed on verification procedures or mechanisms.

Another significant issue that arises when revenue bonds to fund ecosystem services projects is what portions of those projects the bonds can actually pay for. The provision of ecosystem services typically requires the installation of some type of physical infrastructure as well as the ongoing maintenance of that infrastructure. In many cases, funds raised by revenue bonds can be used for the acquisition of new physical capital, but there may be restrictions on using bond funds to pay for ongoing operations and maintenance costs associated with the provision of ecosystem services.

EPA's recent report on green infrastructure notes that to date, most operations and maintenance costs for green infrastructure projects are estimates based on engineering estimates and that additional experience with actual projects is needed to verify the costs of maintaining green infrastructure.[62] As a result, there are not yet sufficient data to determine whether operations and maintenance costs associated with ecosystem services projects pose a significant impediment if public funds are not available to cover the ongoing costs.

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[59] For a summary of state balanced budget requirements see, National Conference of State Legislatures, NCSL Fiscal Brief: State Balanced Budget Requirements 1-4 (2010), *available at* http://www.ncsl.org/documents/fiscal/StateBalancedBudgetProvisions2010.pdf.
[60] *See* 26 U.S.C. § 150(b)(5).
[61] Tex. Const. Art. 16 § 6.
[62] EPA, *supra* note 1, at 7.

- Research should evaluate the extent to which the expenditure of municipal bond funds can be used to support ongoing operations and maintenance expenditures.

- Research is required to understand better the actual operations and maintenance costs associated with maintaining ecosystem services projects once they are constructed.

Regardless of whether funding is derived from taxes or revenue bonds, some states and municipalities may face legal restrictions on their ability to spend public funds for provision of urban ecosystem services. Utility regulatory commissions are typically charged with procuring the lowest cost service available in order to protect consumer rate payers. Therefore, if green infrastructure programs for stormwater retention, for example, are selected as an alternative to large, traditional "grey" infrastructure, states and municipalities may be limited in their ability to adopt such programs or fund any costs that go above and beyond those required by a non-ecosystem services approach.[63] Not all states are uniform in their requirements to provide the lowest cost service, however. Some states provide for consideration of other factors in the public interest beyond the lowest cost service, such as the need for diverse energy sources.

Municipalities that directly operate public utility services may have opportunities to charge special fees that provide a source of revenue for ecosystem services projects. For example, some municipalities impose a surcharge for stormwater that is related to the amount of impervious surface on a property. These funds could be used to provide public funding for green infrastructure projects that minimize stormwater flows. In Philadelphia, non-residential properties are charged a stormwater utility fee based on the amount of impervious surface on a property, and property owners may reduce their stormwater fees by implementing green infrastructure projects on their property.[64]

- Research should review public utility commission regulations to determine whether legal reform is necessary to permit payment for ecosystem services.

- What happens if government agencies invest in advanced planning and public infrastructure development only to find that the need for these projects and fees to pay the debt on them fail to materialize or decline over time?

Encouraging Private Parties to Pay for Ecosystem Services

Given the limitations on the use of public funds for ecosystem service activities, the ability of states and municipalities to create incentives for private parties to invest in the infrastructure and land management practices is critical. Possible strategies range from voluntary conservation easements to additional regulations that require investment in or preservation of ecosystem services.

Private sector investment in ecosystem services can prove attractive for compliance purposes when they can be demonstrated to result in lower costs for regulated entities than conventional approaches. There are numerous examples of parties adopting ecosystem services practices to fulfill requirements under the Clean Water Act, including using riparian shade to address thermal total maximum daily load requirements. For example, ATI Wah Chang, a specialty metals manufacturer, and Weyerhauser joined with the cities of Albany and Millersburg, Oregon, to formulate a unique solution to

[63] Note that in fact one of the major reasons for the promotion of green infrastructure programs is that they are projected to result in significant cost savings when compared to green infrastructure. However the costs of a green infrastructure project will be highly location and context specific.
[64] http://www.phillywatersheds.org/whats_in_it_for_you/reduce-your-stormwater-fees.

excessively warm effluents into the Willamette River. They constructed 39 acres of wetlands designed to cool effluent and meet the requirements of the applicable TMDL.[65] The resultant Albany-Millersburg Talking Water Gardens is designed to cool nearly 13 million gallons of water from industrial and municipal sources each day and also provides co-benefits such as nutrient removal prior to discharge.[66]

Traditionally, conservation easements have been used to preserve open space in rural settings.[67] The property owner generally agrees to preserve the land as open space in exchange for a direct payment from the government, a tax benefit, or some other benefit conferred by the government.[68] The same concepts could be applied in the urban environment to create space for ecosystem services. For example, where open space exists along floodways, municipalities could seek the voluntary dedication of easements to leave such space open as a spillway for flood waters.[69] Similarly, municipalities could potentially seek dedicated conservation easements over green roofs, requiring owners to maintain them over time. For the property owner to receive tax benefits, though, the conservation easement must be dedicated to a government entity or to a qualified land trust, and the receiving entity must satisfy a set of rigorous practices for the establishment, monitoring, and maintenance of the easement to ensure that the conservation goals continue to be served and that IRS standards have been satisfied.[70]

- More research is needed to understand the extent to which conservation easements or similar voluntary easements could be employed in urban settings to enhance the provision of ecosystem services.

- Such research should include geospatial and ecological analyses to determine where opportunities for easements exist and their potential for resilience to changing conditions, economic analysis to determine what types of incentives may be necessary to secure the voluntary dedication of easements, and legal research to better define the structure of such easements—particularly if they are applied to novel ecosystem services such as green rooftops.

States and municipalities may also be able to use their land use planning authorities to incorporate space for ecosystem services into city general plans and master plans for larger developments. In amending city general plans, there may be opportunities to designate particular tracts of land for ecosystem services, requiring future development to meet certain conditions that secure the desired ecosystem services.[71]

- What are the specific opportunities for cities to incorporate ecosystem services requirements into their master plans?

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[65] *Talking Water Gardens Technical Profile*, 1 (City of Albany 2010), *available at* http://twg.cityofalbany.net/wp-content/uploads/2010/08/Talking-Water-Gardens-Technical-Profile-August-2010.pdf.
[66] *Id.*
[67] The Law of Easements & Licenses in Land § 12:2
[68] *Id.*
[69] For an example of a flood conservation easement deed see http://www.water.ca.gov/floodmgmt/fpo/sgb/fpcp/docs/Sample_Conservation_and_Flood_Easement.pdf.
[70] Treas. Reg. § 1.170A–14. Many state and local governments that wish to receive conservation easements have established government land trusts to receive and hold them or designated particular agencies to have the power to receive or hold particular kinds of conservation easements.
[71] *See generally* JULIAN CONRAD JUERGENSMEYER AND THOMAS E. ROBERTS, LAND USE PLANNING AND DEVELOPMENT REGULATION LAW, 3RD ED. 13-38 (2013) (describing the history of and legal authorities for local planning, including amendments to comprehensive plans, planning for environmental considerations, and judicial deference to plan amendments).

- Will incorporation of ecosystem services into master plans increase adherence to and enforcement of plans.

States and municipalities could also condition future development permits on the adoption of particular measures to promote ecosystem services. This can be done through municipal ordinance, on a permit-specific basis, or as a combination of the two. For example, Atlanta has a post-development stormwater management ordinance that requires new development and redevelopment projects to implement measures to control stormwater runoff once construction is complete.[72] This ordinance was recently modified to require that projects treat the first inch of stormwater with green infrastructure.[73] While such permitting requirements have the potential to be important tools, they are subject to legal restrictions under the takings doctrine. Technically, requirements to install or preserve ecosystem services would be exactions, which are only valid to the extent that they have a significant nexus with and are roughly proportional to the projected impacts of the proposed development.[74] For example, requiring a new development in a flood plain to leave open space to serve as a spill way would be constitutional so long as the amount of open space required was roughly proportional to the projected additional impacts caused by the proposed development. The Supreme Court's recent decision in *Koontz* held that requirements to pay money can be exactions, also subject to takings analysis.[75]

- In light of recent case law, additional research can provide clarity on the constitutional limits of municipalities' ability to require the provision of ecosystem services or related in lieu fees as a condition of new development permits.

- Empirical research on cities' practices with respect to green-infrastructure exactions is also needed. For example, following the *Dolan* decision, social scientists discovered that cities had mostly been under-exacting, not over-exacting, and the decision proved actually to empower cities to seek more exactions, contrary to some commmentators' initial concerns.[76]

Liability, Compliance, and Insurance Issues

A significant number of recent green infrastructure projects undertaken by municipalities have arisen from obligations under legal settlements, often addressing cities' liability for discharges from their stormwater or combined sewer outfalls that exceed the limits set in permits issued under the Clean Water Act. The consent decrees settling these lawsuits may call for some elements of green infrastructure to be included in plans to reduce a city's stormwater discharges. For example, the recent modification to the consent decree for the City of Chicago requires the implementation of a Green Infrastructure Plan.[77] The Plan itself has a number of required elements including that the city agency "work with partners and stakeholders to plan legal and institutional mechanisms (1) to preserve and maintain constructed green infrastructure projects that are put in place under Section III and (2) to ensure that future site or land use changes do not result in the loss of the runoff reduction benefits of Green Infrastructure projects."[78]

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[72] *See* http://www.atlantawatershed.org/default/?linkServID=95836454-BAB0-48DC-AABE36297717215C&showMeta=2&ext=.pdf.
[73] *Id.*; *see also* Implementing Green Infrastructure: Atlanta's Post-Development Stormwater Management Ordinance, *available at* http://www.atlantawatershed.org/default/?linkServID=513ADAB0-6965-4F92-AEBB38FC264C3DF6&showMeta=2&ext=.pdf.
[74] Dolan v. City of Tigard, 512 U.S. 374 (1994); Nollan v. California Coastal Commission, 483 U.S. 825 (1987).
[75] Koontz v. St. Johns Water Management District, 133 S.Ct. 2856 (2013).
[76] Ann E. Carlson & Daniel Pollak, *Takings on the Ground: How the Supreme Court's Takings Jurisprudence Affects Local Land Use Decisions*, 35 U.C. DAVIS L. REV. 103 (2001)
[77] Consent Decree, United States v. Metropolitan Water Reclamation District, No. 11-cv-08859 at ¶43 (N.D. Ill. Dec. 14, 2011).
[78] *Id* Appx. E

Similarly, the recent modification to the consent decree for Seattle encourages the city to use green infrastructure measurements as appropriate in its long term control plan, and the 2010 modification to New York City's combined sewer overflow consent decree calls for the replacement of some grey infrastructure with green infrastructure projects.[79] The threat of financial liability for city agencies or utilities creates both legal and political justifications either for charging fees to sewer users, for example, that can be used for green infrastructure projects or using general funds for liability-offsetting green infrastructure.

Research into the source of funding used to meet consent decree obligations may shed light on mechanisms that could be used for public financing of ecosystem services projects. Relying on urban ecosystem services to meet compliance obligations could provide an important incentive for increased provision of services, but this raises a host of challenges.

- What is the potential for an opportunistic strategy of using consent decrees to drive major investments in urban ecosystem services across cities?

- To promote greater reliance on urban ecosystem services for regulatory compliance, consistent and credible compliance metrics must be developed for urban ecosystem services.

- In the event that green infrastructure measures fail or do not provide the expected level of services, what are the consequences of noncompliance? Can municipalities still be required to make additional investments in traditional "grey" infrastructure to meet the substantive requirements of the law?

- Apart from consent decrees, what other alternative compliance and enforcement pathways for ecosystem services approaches are feasible?

- If natural infrastructure fails to provide the expected benefits, who bears the liability for that failure?

The above examples raise a number of interesting questions that will be applicable to all ecosystem services projects. These questions include how to handle liability for ecosystem services projects, what types of insurance may be available to protect a party in the event of an ecosystem services failure, and how compliance with ecosystem services requirements can be measured.

While the proliferation of green infrastructure requirements in Clean Water Act consent decrees provides an important example of the opportunities to increase the application of ecosystem services, it also demonstrates a genuine liability limitation. The general framework of the major environmental laws in the United States relies on compliance with substantive numeric standards as measures of both environmental quality (e.g. the National Ambient Air Quality Standards or Water Quality Standards) and facility specific compliance (typically through the application of facility-specific emission rates). In addition, the legal framework imposes separate and distinct numeric standards for each pollutant, often ignoring co-benefits of green infrastructure that might improve environmental performance across several measures but fail to meet all numeric standards. While ecosystem service programs can be designed to meet particular environmental quality objectives, research on their ability to meet specific numeric

[79] Consent Decree, United States v. Seattle, No. 13-cv-678, at 62 (W.D. Wash. Apr. 16, 2013); Order on Consent, *In re* Violations of Article 17 of the Environmental Conservation Law, DEC Case No. CO2-20110512-25 (Oct. 11, 2011).

performance criteria is limited.[80] As a result, entities using ecosystem services to meet substantive legal obligations may find that they are left with residual risk and additional compliance cost if the ecosystem services projects fail to function as designed.

Entities adopting ecosystem services approaches to meet legal obligations may wish to purchase a type of pollution liability insurance that would provide protection in the event that the project fails to deliver the required services. Moreover, when ecosystem service projects require financing for major physical infrastructure, it may be impossible to finance a project if it cannot be insured.

While in some respects uncertainty over the performance of ecosystem services seems like a novel risk, all pollution control technologies have some risk of failure from mechanical breakdowns. Viewed in this light, the risk of using ecosystem services for compliance can be managed in much the same way that the traditional risk of pollution equipment failure is and theoretically should be insurable.

A further complication arises when many of the activities needed to guarantee the provision of an ecosystem service are outside of the control of the entity with the compliance obligations. For example, a municipality using green infrastructure to comply with a Clean Water Act stormwater requirement must rely upon the actions of many individuals on their private property to insure that the stormwater reduction benefits are achieved.

Another way to address the risk of provision failure is through the issuance of time-limited credits that can be re-issued if a project continues to perform the ecosystem services expected of it. For example, in Washington, D.C.'s stormwater program, a landowner can be issued tradable credits for green infrastructure installed on his private property.[81] The credit is valid for a three year period.[82] If during that three-year period the District government learns that the landowner has not maintained the project, the landowner is required to pay back any funds received through the sale of the stormwater credit.[83] If, at the end of the three-year period, the project continues to function as intended, a new credit can be issued after inspection by the District government.[84] The research questions below highlight the need for more research on the insurability of ecosystem services.

- What types of insurance products are appropriate for urban ecosystem services? Would insurance cover the physical aspect so the ecosystem services project itself or just the service that it is supposed to be providing?

- Can insurance provide meaningful coverage or are new products needed? If insurance is infeasible, is self-insurance by the party responsible for providing the service possible?

- Can insurance protect against the risk of failure or noncompliance if private landowners do not maintain their components of the ecosystem services project? What contractual terms could provide adequate protections against this risk in case of payments for ecosystem services?

- What are the costs of monitoring green-infrastructure projects for performance and the related administrative costs of administering a time-limited credit system?

[80] Note that EPA but much work remains to refine the design of projects to ensure that they can meet numeric, legally enforceable performance criteria.
[81] D.C. Municipal Regulations Ch. 5 Tit. 21, *available at* http://ddoe.dc.gov/sites/default/files/dc/sites/ddoe/page_content/attachments/2013%20SW%20Rule.pdf
[82] *Id.* at § 531.10.
[83] *Id.* at § 532.5
[84] *Id.* § 531.10.

C. Governance

The services that ecosystems provide to urbanized areas are both dynamic and multifaceted, varying in scale and effectiveness. As a result, identifying the appropriate governance structures to ensure the provision of ecosystem services to urban is complex. By "governance," we mean the institutional arrangements, both governmental and civic, as well as the associated processes that achieve and maintain urban ecosystem services. The paragraphs below set out the key research areas surrounding the institutional aspects of ecosystem service provision as well as specific questions that merit further study.

Scale of action

Ecosystem services can be provided at various spatial and temporal scales depending upon the type of service. Water filtration services from forested lands within a watershed often occur at a regional scale spanning multiple political jurisdictions. Services provided more locally, such as bio-retention swales or rain gardens to mitigate stormwater flow, are often within the control of a single entity. Services also vary across time scales. For example, management decisions about the mix of ecosystem services provided today may impact the extent of ecosystem services available to future generations. As a result, governance of urban service provision cannot be one-size-fits-all. The list below highlights the key research questions raised by spatial and temporal aspects of service provision.

- Are services that are provided locally (such as green infrastructure at the site level) more efficiently provided by municipal officials than services that are provided regionally (such as the filtering of precipitation by forested lands in distant areas within a large watershed)?

- When service-sheds cross political boundaries, does that impede ecosystem service protection efforts? If so, how have actors overcome this challenge? Is voluntary, intermunicipal cooperation a viable option?

- Are particular levels of government more effective in administering particular policy mechanisms (e.g., property law, zoning, voluntary programs, payment for ecosystem services, etc.)?

- How do governance mechanisms address temporal challenges of service provision where near-term needs of the current generation are valued more than long-term needs of future generations? How is this affected by the perspective of current actors involved in provision and consumption of ecosystem services?

- How does the flow of information between various levels of governance actors either promote or impede provision of ecosystem services?

Parties

Ecosystem service stakeholders span a wide range of actors, including providers, beneficiaries, and institutional intermediaries. How these parties interact and communicate is critical to the management choices that determine the governance of service provision. The list below identifies key questions about the role of parties in the provision of urban ecosystem services.

- How does the structure and financing of utilities/agencies influence their efficiency and effectiveness in protecting ecosystem services?

- How can future generations be represented at the table during policy discussions regarding ecosystem services?

- Does the scale or type of ecosystem at which governance activities occur affect which stakeholders participate in governance and the degree and methods of their participation?

- What mechanisms can serve as scale-crossing agents, i.e., able to provide information and perspective on how aggregated development decisions at the site-level scale influence the provision of ecosystem services at the municipal or regional levels?

- Which participatory processes will engage a wide range of stakeholders effectively in ecosystem services governance over time? How do legal actions (e.g., litigation, legislation, regulation) affect stakeholder participation and cooperation, as well as governance efficacy? Which participatory processes are most adaptive to changing conditions over time?

Service targeted

Different ecosystem services vary in their characteristics, operating across different spatial scales, locally to globally, as well as in their economic value and relationships with the legal and economic institutions and norms. Some services are given a strong value by existing policy/regulation (e.g., the Clean Water Act gives value to stormwater mitigation), while others do not have a clear regulatory mechanism giving value to them. The questions in this section consider how the key characteristics of an ecosystem service affect programs targeted to maintain or enhance that ecosystem service.

- Should specific urban ecosystem services be prioritized for management, and if so, how does this influence governance structure?

- Which ecosystem services are highly valued by current law and policy? Are there "gaps" in coverage that allow some important ecosystem services to be overlooked by policymakers?

Environmental objectives across government silos

The links between human land management actions and the level of ecosystem function are quite complex, depending on the ecosystem function in question, local ecological context, and specific characteristics of management actions. Moreover, management of lands to maintain or enhance a particular ecosystem function may have tradeoffs, degrading ecosystem function in other respects. The questions in this section describe how land managers consider these complexities in achieving specific environmental objectives, given that institutional structures are not generally designed to address these cross boundary interactions.

- What is the link between resource management and service provision? How do governance structures influence what is measured and how this is counted?

- How can actors overcome "silo" agency configurations with a narrow focus to promote multi-faceted ecosystem service provision (e.g., not just stormwater here, habitat there)?

- Are there examples of cities with strong sustainability (or similar) offices or plans able to overcome agency silos? Are these offices effective? If so, why are they effective?

- Are comprehensive and individual-agency planning processes capable of optimizing multiple service provision simultaneously? What roles do or can adaptive planning processes have?

Accounting for Ecosystem Services

Provision of ecosystem services may compete with traditional infrastructure in competitive budget environments to help defray compliance obligations already faced by a government entity. Moreover, regulatory systems have not traditionally focused on green infrastructure as a means to achieve compliance. Part of this is due to inadequate information.

Characterization of the services that are provided in urban areas can facilitate a location–specific valuation and help discern the conditions of ecosystems in local areas and their relationship to communities. Specifically, such characterization can assist communities in prioritizing trade-offs from the menu of ecosystem services that are subject to local pressures and needs. Some communities have partnered with governmental and nongovernmental entities to value the ecosystem services of particular resources in particular locations. Examples include the work done to value urban forest services, the long-standing and continuing work of wetlands value in the context of artificial wetlands and wetland enhancements, and the varieties of open space values and storm water control benefits through green infrastructure. Overall, though, little is understood about the ways and methods that ecosystem service values might be incorporated into local decision-making. At a minimum, there needs to be a much more grounded understanding through detailed case studies of how local governments practically rely on ecosystem services.

- To assist understanding of urban ecosystem trade-offs, researchers should compile an ecosystem services inventory the relative costs and benefits of service provision, and how provision of services can conflict.

- Economic studies to fill gaps in the valuation of urban ecosystem services can lead toward the development of robust meta-analysis and reduced uncertainty in benefit-transfer methods for urban systems, reducing costs and time associated with monetizing services.

- What are the traditionally leveraged policies for provision of ecosystem services? What non-traditional approaches have been employed and could be translated to more widespread implementation?

- How can information on the efficacy of specific ecosystem services be provided among different actors so that the governance system is able to adapt to changing circumstances?

Ownership, enforcement and sanctioning

Both scholarship and anecdotal evidence note multiple instances of ecosystem services being impeded by "administrative silos." Ecosystem services require very different administrative structures and management than that associated with traditional gray infrastructure. Scales and maintenance requirements differ as do both affected and responsible individuals. Particularly in situations involving multiple individuals or communal ownership, such as distributed green infrastructure in urban

environments, identification of responsible parties and enforcement of management responsibilities can be a challenge.

- What are the pathways for management of urban ecosystem services? Are there examples of decentralized management of services, and if so, how have these been initiated/implemented?

- How is enforcement and ownership structure tied to compliance?

- What can the behavioral sciences tell us about the methods that best develop environmentally responsible behaviors among individuals and organizations? Do these behavior-shaping methods include robust stakeholder participation in rule development and/or participation in rule enforcement? What are the implications for the cognitive framing of ecosystems and their values to urban communities?

How does governance influence adaptive management?

There is an established and expanding literature on the subject of adaptive governance and ecosystem resilience. Implementing multiple management strategies or adopting new governance structures is easier said than done, however. In light of the benefits identified with adaptive management and adaptive governance structures, how can real-world constraints be overcome to better accommodate the provision of ecosystem services?

- Given institutional constraints, how can governance structures be better designed to accommodate adaptive management of urban ecosystem services? What are the abilities of a given governance structure to revisit decisions affecting service provision?

- What are the relationships among adaptive management, adaptive planning, and adaptive governance, particularly at the local scales at which cities operate?

- Given uncertainties in ecosystem dynamics and their thresholds, how can resilience science be employed practically and concretely to identify specific thresholds in urban ecosystems that could trigger their collapse or substantial transformation if crossed, and how can those thresholds be integrated into urban ecosystem services policies?

IV. Conclusion

Whether described as green infrastructure, urban ecosystem services, or some other term, there is undeniably growing interest across the country in the use of natural features and managed landscapes to provide valuable services to city residents. In certain circumstances, the benefits nature provides for human health and well-being are likely to be both extensive and important in urban spaces. Not surprisingly, the challenges of providing urban ecosystem services to date have largely been analyzed through the perspective of specific disciplines – legal scholars writing for lawyers, urban planners writing for their community, etc. This article has sought to bridge disciplinary divides, bringing together active researchers from a range of fields to identify the most important research questions raised by the provision of urban ecosystem services. Our hope is that the issues and challenges identified above will catalyze directed research in this burgeoning and important field.