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The Concept of Ecosystem Services in Adaptive Urban Planning and Design: A Framework for Supporting Innovation

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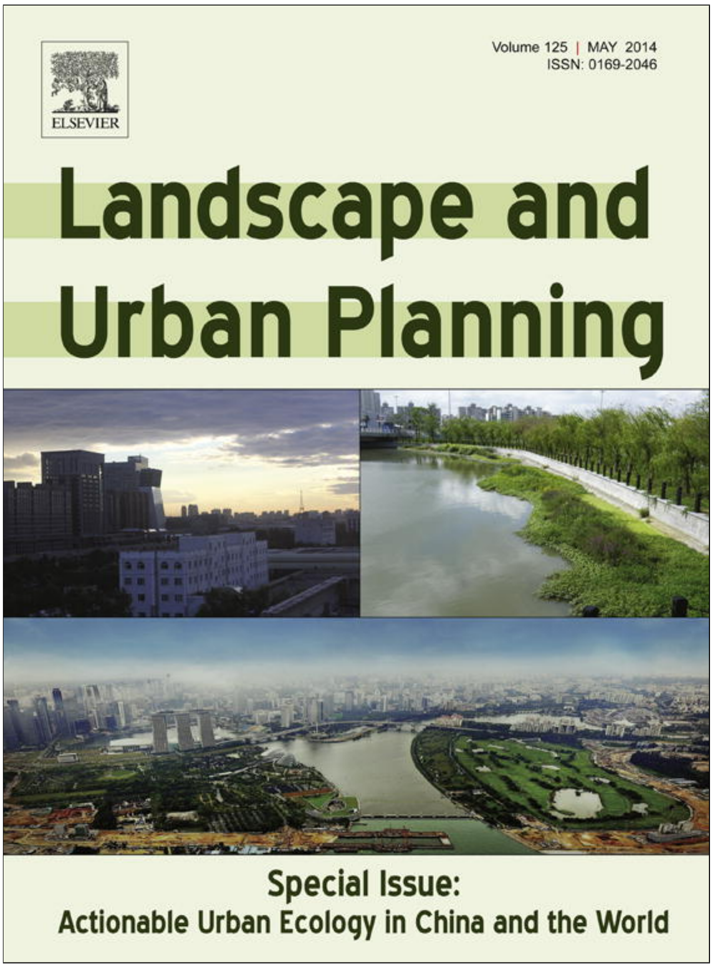
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Research Paper

The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation

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HIGHLIGHTS

- Using citizen/civic science as a strategy to promote transdisciplinarity.
- An adaptive method to promote innovation via small, safe-to-fail design experiments.
- Suggested indicators to monitor ecosystem services provided by green infrastructure.
- Proposes a core/common set of metrics to assess ecosystem services.
- A transdisciplinary adaptive design/planning model to support urban sustainability.

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ABSTRACT

Recent research and professional interest in planning for sustainable and resilient cities emphasizes the assessment of a broad spectrum of urban ecosystem services. While such assessments are useful to establish specific benchmarks, and for measuring progress toward sustainability and resilience goals, they do not motivate, or support the innovations required to provide specific ecosystem services as an intentional part of routine urban and infrastructure development activity by municipalities and professionals. In this context, predictions for unprecedented future urbanization and development of new urban infrastructure represent a unique opportunity to "learn-by-doing". Significant advances in urban sustainability have recently been made through transdisciplinary collaborations among researchers, professionals, decision-makers and stakeholders. However, these advances, often through pilot projects, have limited transferability to other cities due to the inherent biophysical and cultural uniqueness of the city in which they originated, and of the projects and plans themselves. The promise of practicing "learning-by-doing", therefore, remains an elusive goal, not yet fully integrated with urban development. In this essay, a framework for "safe to fail" adaptive urban design is proposed to integrate science, professional practice, and stakeholder participation. The framework is a transdisciplinary working method, and includes experimental design guidelines, monitoring and assessment protocols and strategies for realizing specific urban ecosystem services integral with urban development. The "safe-to-fail" adaptive urban design framework encourages and rewards innovation in a low-risk context – while assessing the achievement and performance of the specific intended ecosystem services.

1. Introduction

Most people today live in cities and urbanization is a megatrend that is expected to continue throughout the world at least until mid-century (UN Habitat, 2006). Urbanization has been characterized as "a massive, unplanned experiment in landscape change" (Niemelä et al., 2011) leading to significant conversion of land to urban development. For instance, the Brookings Institution predicts that 46% of the built environment in USA will be new or replaced between the years 2000–2030 (Nelson, 2004). Similar projections predict that as much as 60% of the built environment of the world will be new or replaced by the year 2050. It is predicted that the developing world, especially in Africa and Asia will experience the majority of 21st century urbanization (Cohen, 2006). Cities will, however, experience a full range of demographic change from significant growth

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to decline and shrinkage (Alfsen et al., 2011). This future urbanization is unprecedented and emphasizes the need for innovative approaches to generating knowledge before, during and after the process of urbanization in an adaptive mode. Thus, new approaches to urban planning and design will be increasingly important to address the challenge of sustainable urban land use (Keeley, 2007).

Urban ecosystems provide vital services for urban dwellers (McDonald & Marcotullio, 2011). Important contributions have been identified from various ecosystem types, even from previously unrecognized urban biotopes, including domestic gardens (Cilliers, Cilliers, Lubbe, & Siebert, 2012; Ross et al., 2012; Standish, Hobbs, & Miller, 2014). It is increasingly recognized that ecosystem services need to be incorporated into urban planning (Colding, 2011). Professionals, planners and designers need to make decisions in response to approval and development schedules. However, the "traditional" professional timeframe mandates an "imperative to act" that relies on readily available, existing knowledge and established best practices – typically without the opportunity to conduct new research. This imperative tends to favor decisions based on existing knowledge, and to inhibit innovation (Holling, 1978; Kato & Ahern, 2008). The challenge of providing ecosystem services for urban sustainability planning and design will rely on emerging urban planning and design theory and new knowledge in design and engineering (Calkins, 2005; Steiner, 2011). Transdisciplinarity, implying co-production of knowledge by scientists, planning professionals and urban dwellers is a key to realize the potential of this planning approach (Tress, Tress, & Fry, 2005).

The aim of this essay is (1) to explore ways to enhance transdisciplinary and innovative urban planning, and (2) to propose a framework for "safe-to-fail" adaptive urban design – a design concept through which pilot projects can test innovative, but unproven solutions in a responsible and informed manner, with a low risk of failure (Ahern, 2011; Lister, 2007). The "safe-to-fail" framework can provide a structure to integrate science, professional practice, and stakeholder participation in experimental designs or pilot projects, of small spatial extent such that their failure would not result in major disasters or politically negative publicity. The framework is a transdisciplinary working method, and includes experimental design guidelines, monitoring and assessment protocols, and strategies for including urban ecosystem services into urban development. This approach encourages planning professionals to apply principles of experimental design to urban plans. While these principles are basic in science, they are not commonly practiced by planning professionals. Thus, adaptive design including the experimental approach can help planning professionals to practice "learning-by-doing" in a transdisciplinary manner.

2. Concepts of an adaptive planning framework: green infrastructure and ecosystem services

The concept of green infrastructure has emerged as a way to secure the provisioning of ecosystem services in human-dominated landscapes (Colding, 2011). In this paper we use the definition of Ahern (2011: 159) where green infrastructure is defined as "Spatially and functionally integrated systems and networks of protected landscapes supported with protected, artificial and hybrid infrastructures of built landscapes that provide multiple, complementary ecosystem and landscape functions to the public, in support of sustainability". Articulating the ecosystem services provided by green infrastructure is an emerging research theme (Dobbs, Escobedo, & Zipperer, 2011; James et al., 2009; Soares et al., 2011; Tratalos, Fuller, Warren, Davies, & Gaston, 2007; Tzoulas et al., 2007) showing that green infrastructure delivers measurable ecosystem services and benefits that are fundamental to the concept of the sustainable city. Because green infrastructure is, by definition, multifunctional, and can function at multiple scales, the ecosystem services concept is useful to explicitly identify and assess its multiple functions. In terms of planning, green infrastructure addresses the "imperative to act" to make future urban environments more sustainable in the context of, and as a direct result of, routine urban (re)development.

Three related perspectives on applying scientific knowledge in planning and design have been articulated in recent literature. Firstly, design is any intentional change of landscape pattern for the purpose of sustainably providing ecosystem services while recognizably meeting societal needs and respecting societal values (Nassauer & Opdam, 2008). Secondly, designed experiments are transdisciplinary partnerships of scientists, planners and designers collaborating to integrate experiments into the urban mosaic, balancing ecological goals with context, esthetics, amenity and safety (Felson & Pickett, 2005). Thirdly, adaptive design is a process and approach in which selected urban plans and projects explore innovative practices and methods; informed by ecological knowledge and research design. Adaptive plans and projects are open to design innovations and creativity. They are monitored and analyzed to learn with the goal of gaining knowledge to apply to future projects (Ahern, 2012; Lister, 2007; Rottle & Yocom, 2010). Adaptive design is well-suited to "safe-to-fail" design experiments where innovations are implemented and monitored. These activities take place in an experimental, but small spatial extent mode where the possibility of failure is real. Importantly, the risk of failure is explicitly understood and accepted by decision-makers and stakeholders (Ahern, 2011).

3. An adaptive planning and design model

While adaptive management has been practiced in natural resource management for some time, adaptive and "safe-to-fail" design remains a largely untested idea in urban planning and design. It represents a higher level of transdisciplinary collaboration than currently practiced among ecologists, design professionals and other stakeholders (Musacchio, 2009, 2011). Here, a framework for adaptive design is proposed based on a scientific approach to experimental design and a predetermined set of indicators and metrics of ecosystem services. The framework is conducted in a transdisciplinary mode with various stakeholders and decision-makers engaged throughout the design process with scientists and decision-makers.

Adaptive design challenges professionals to understand, and apply accepted principles of experimental design to conceive, implement, monitor and analyse resulting plans and built projects. While these principles are basic and fundamental in science, they are not familiar, or commonly practiced by design and planning professionals. Adaptive design with its experimental approach can help planning professionals to practice learning-by-doing", while keeping in mind that planning is not science, but social action with scientific, technological and legal underpinnings (Nilsson & Florgård, 2009). The difference in scientific and professional cultures, which is often referred to as creating a "knowing-doing gap" is well known in environmental management (Knight et al., 2008) and may also be the reason that adaptive design has yet to be widely practiced.

The adaptive design and planning framework outlined below (Fig. 1) is organized to integrate and operationalize experimental design principles with professional practice. If this process can be conceived, implemented, monitored and analyzed in a genuinely transdisciplinary manner, it holds the potential to generate evidence-based, scientifically defensible knowledge in the course of routine planning and design practice. Our proposed six steps (Fig. 1) are somewhat similar to, but more specific to planning

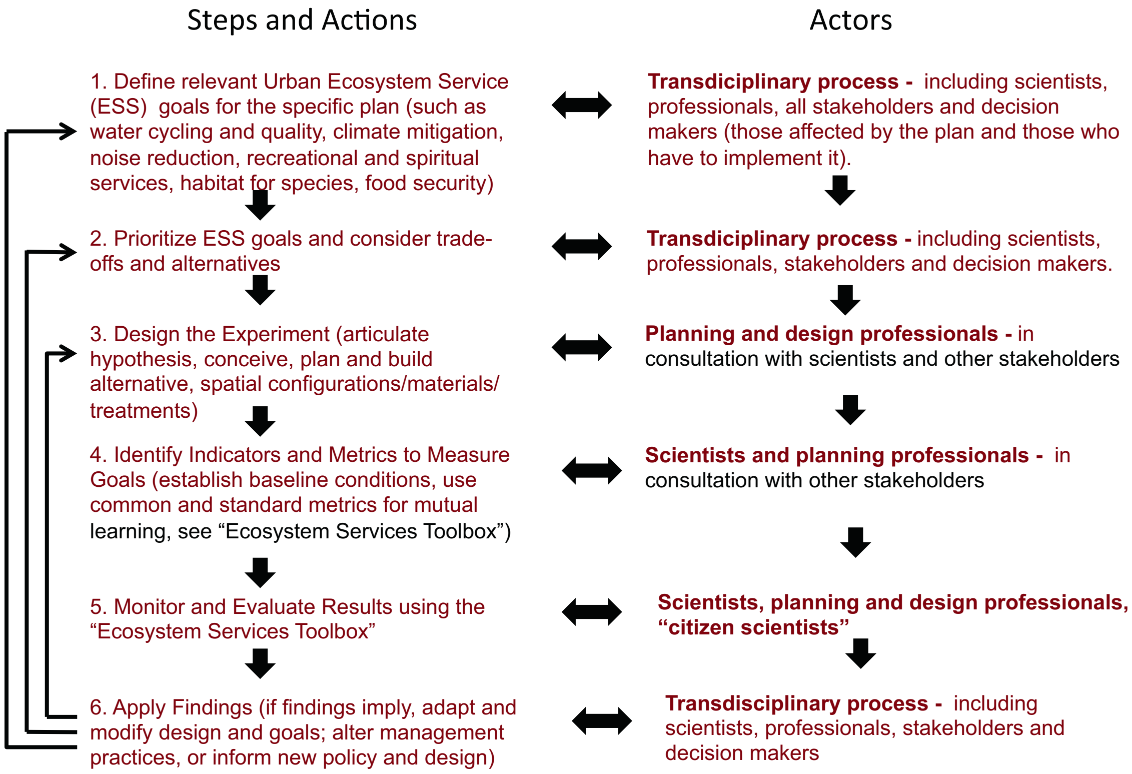

Fig. 1. A transdisciplinary adaptive design and planning model.

and design than the stepwise approach proposed by TEEB (2011) for including ecosystem services in urban management (decision making and policy). It is also consistent with the monitoring component of SITES, the recent American program for certification of sustainable landscape practices (Sustainable Sites, 2013).

The main thrusts of the above model are its dynamic feedback loops and transdisciplinary nature. Monitoring is vital for the continuous refinement and testing of the framework. If monitoring shows that targets are not met, corrective measures should be taken in terms of revising the goals, changing planning practices or improving the implementation of the plan (Fig. 1). Planning professionals, scientists, decision-makers and citizens are involved in all the steps but the relative role of these actors varies between steps.

It is a challenge to involve urban residents in any participatory process on the local government level. Citizen or Civic Science, also known as participatory science, offers a promising approach for transdisciplinary collaborations (Dickinson et al., 2012). Civic science can form a useful bridge between academic research and the community-at-large. Civic science enables collaboration and creates a more engaged, knowledgeable and ecologically literate citizenry by bringing science into contact with the public (Clark & Illman, 2001) often in environmental justice decisions (Ferketic, Latimer, & Silander, 2010; Scott & Barnett, 2009). Adaptive design experiments using the civic science approach are much needed in urban planning and design and we need good workable examples that can be regarded as "best practices". Such best practices are still largely lacking in urban areas. On the contrary, there are examples of the difficulties of using civic science in the urban context. For instance, the ecocircle concept of vegetable cultivation in private and community gardens in Potchefstroom, South Africa has failed to a large extent (Cilliers, 2010). About half (57%) of the participants discontinued their activities, mainly due to a lack of ecological knowledge and conflicts with the cultural beliefs of the participants (Cilliers, 2010).

4. Urban ecosystem services assessment toolbox

In steps 4–6 of the adaptive design framework (Fig. 1), an "Ecosystem Services Toolbox" is proposed for monitoring and evaluating results of the framework and for modifying and revising steps 1–3, if necessary. Here, we present the rationale and foundations of such a toolbox. The adaptive design framework demonstrates how design decisions can be conceived as experiments in a genuinely transdisciplinary manner, including monitoring data on ecosystem services performance as outlined in the ecosystem services toolbox (Fig. 2).

Research on ecosystem services in urban environments has articulated foundational theory that addresses the actual and potential contributions of professionals in addressing urban ecological challenges (Grimm, Grove, Pickett, & Redman, 2000; Pickett et al., 2001; Pickett, Cadenassso, & Morgan, 2004). Subsequent research has addressed the specific performance of ecosystem services through planning, design and green infrastructure (Calkins, 2005; Jansson & Lindgren, 2012; Lovell & Johnston, 2009). While the research is sound and robust, it lacks transferability because of the non-generalizable nature of the research. However, planners and designers seek standardized indicators and metrics that are understandable, transferable, robust and defensible. The transferability and exchange of knowledge could grow substantially, if urban ecosystems services research could agree on a common set of ecological indices and metrics. The idea here is to start developing a common baseline set of measures. A similar effort was made to articulate a "core set" of landscape metrics for use in landscape planning, to address the minimal use of landscape metrics in landscape planning (see Leitão & Ahern, 2002). Similarly, in step 3 of the stepwise TEEB approach (TEEB, 2011) three different types of assessment methods were described, namely quantitative (as we proposed here), monetary (using relevant economic valuation methods) and qualitative (using consultative techniques with relevant stakeholders as also proposed earlier). Although monetary

Urban Ecosystem Services (examples)	Indicators and Metrics	Examples/References
Stormwater infiltration	% impervious cover, soil permeability, slope of surface	SEA Street, Seattle (http://www.seattle.gov/util/groups/public/@spu/@usm/documents/webcontent/spu02_019984.pdf), Portland Oregon Green Streets (http:www.portlandoregon.gov/bes/article/167583), Helsinki Stormwater Strategy (in Finnish: http://www.hel.fi/static/hkr/julkaisut/2008/hulevesistrategia_2008_9.pdf
Water quality	Total N, Total P, BOD, Turbidity, pH	Staten Island Blue Belt (NYWEA 2009)
Habitat provisioning	Index of Biotic Integrity (IBI), Fish Index of Biotic Integrity (FIBI), City Biodiversity Index (CBI)	Seattle SEA Street, Salmon Restoration (Seattle Public Utilities (online) City Biodiversity Index (http://www.cbd.int/authorities/gettinginvolved/cbi.shtml)
Air quality	Total particulates	Boston Urban Ecology Institute (online) Air Quality in Finland (http://www.ilmanlaatu.fi/)
Urban climate	% tree canopy, maximum daily air temperature, diurnal heat flux	New York City, 1 Million Trees Program (NYC Parks and NY restoration Project (online)
Carbon storage and sequestration	amount of carbon stored by urban trees	10 US cities, Nowak & Crane (2002), indigenous street trees in South Africa (Stoffberg et al., 2010)
Public recreation	Park visitation, activity mapping, "favorite places" identified by residents, and restorative experiences	Stockholm, Sociotope mapping (Ståhle, 2006), Finland (Korpela et al., 2008)
Food security	% urban green area dedicated to agricultural activities, agricultural productivity	Havanna, Cuba – urban agriculture (Altieri, 1999)
Cultural service provision based on cultural heritage and education service potential	Distances between remnant natural vegetation and cultural heritage sites and educational institutions	Cape Town, South Africa – rapid ecosystem service assessment in promoting conservation (O'Farrell et al., 2012)

Fig. 2. Examples of indicators and metrics that have been used to assess ecosystem services in urban settings (See refs. Altieri et al. (1999); Korpela, Ylén, Tyrväinen, and Silvennoinen (2008); Nowak (2002); NYC Parks (2014); NYWEA (2009); O'Farrell, Andersen, Le Maitre, and Holmes (2012); Seattle Public Utilities (2009); Ståhle (2006); Stoffberg, Van Rooyen, Van der Linde, and Groeneveld, (2010)).

valuation of ecosystem services can be valuable as it "translates natural assets into the same currency" as other concerns of local governments (TEEB, 2011), the development of the most appropriate valuation methods and instruments is still a challenge (De Groot, Alkemade, Braat, Hein, & Willemen, 2010; Ring, Hansjürgens, Elmqvist, Wittmer, & Sukhdev, 2010). Thus, we propose a quantitative approach. Following is, therefore, a non-exhaustive list of examples of some indicators and metrics that have been used and that could form components of an urban ecosystems services assessment toolbox (Fig. 2).

5. Conclusions and future research needs

The concept of a "safe-to-fail" adaptive design is nascent and largely unpracticed or tested. This essay offers a framework, rationale and examples of assessment metrics ('toolbox') for adaptive design that aspires to raise the level of transdisciplinary collaboration toward the goal of urban sustainability. Additional research and development is needed to advance this concept, and inspire and support its application. An outline of these future research needs includes:

- Identify a Core Set of Urban Ecosystem Service Indicators and Metrics (by biome, landscape context, ecosystem service, and socio-economic context).
- Develop Experimental Urban Planning and Design Protocols for Urban Projects by project type, spatial extent, and goal.
- Develop a transdisciplinary working method that articulates the respective contributions and working methods of scientists, planning and design professionals, stakeholders and decision-makers and realize the importance of a civic science approach.
- Build a "best practice" portfolio by project type, context, ecosystem service goal, and scale.

It is important that all the above issues are studied and developed in a comparative, global fashion. A global perspective is vital for increased understanding and appreciation of the variation of urban contexts and for better understanding of how humans interact with the urban environment in various parts of the world. A global approach is also needed for sharing best planning practices across cities.

Although adaptive urban planning and design as proposed in this essay is definitely a promising development, we should acknowledge the challenges which lay ahead in implementing this approach. Roberts et al. (2011) discussed "community ecosystem-based adaptation" (CEBA) as part of a general strategy assisting urban residents to adapt to the negative aspects of climate change, amongst other aspects by management, restoration and conservation of ecosystem services, as a good example of "learning by doing". This is also the core message of this essay. According to Roberts et al. it is a misconception that an adaptive process is an easy and cheap alternative to "hard engineering solutions", but emphasized that it might be "more cost-effective, more adaptable and have multiple co-benefits across a range of scenarios and time lines". Roberts et al. highlighted the lack of monitoring the effectiveness of "adaptive interventions" as a large gap in Durban's current CEBA program. Monitoring and the subsequent corrective measures are a vital part of the adaptive planning framework we propose here. For successful monitoring an ecosystem services assessment toolbox is needed for urban areas. In this essay we have discussed the foundations of such a toolbox and we hope that these thoughts encourage researchers and practitioners across the world to continue developing, and pilot testing the toolbox.

Appendix A. Urban development-related ecosystem service assessment resources

Berlin, Germany, Biotope Area Factor

A scoring/regulation policy to promote green infrastructure practices, and protection of biotopes and species for new development in the city of Berlin. http://www.stadtentwicklung.berlin.de/umwelt/landschaftsplanung/bff/index_en.shtml

City Biodiversity Index (also known as the Singapore Index)

The index is a self-assessment tool for monitoring and evaluating biodiversity in cities and is the only biodiversity index for cities specifically. The City Biodiversity Index was developed by experts from around the world, including academic research institutions, experienced local government officials, as well as established organizations specialising in biodiversity and ecosystem services in a city context http://www.cbd.int/authorities/gettinginvolved/cbi.shtml

Green Infrastructure Community of Practice, The Conservation Fund

This CoP promotes the adaptive application of green infrastructure among planners, designers, researchers and managers. http://www.conservationfund.org/green_infrastructure.

Landscape Architecture Foundation (LAF) Landscape Performance Series (LPS)

An initiative of the LAF to evaluate the performance of built projects that aim to provide specific ecosystem services. The program is building a portfolio of documents case studies that will serve as a reference to professionals, researchers and students. http://www.lafoundation.org/research/landscape-performance-series/.

Low Impact Development Center (LID)

LID is a land planning and design approach that emphasizes maintaining, or restoring an undisturbed hydrologic in urban and developing watersheds. http://www.lowimpactdevelopment.org/.

Stockholm Resilience Center

The aim is to create a world-leading transdisciplinary research center that advances the understanding of complex social-ecological systems and generates new and elaborated insights and means for the development of management and governance practices. The center will advise policymakers from all over the world, and develop innovative collaboration with relevant actors on local social-ecological systems to the global policy arena. http://www.stockholmresilience.org/

Sustainable Sites (SITES)

An interdisciplinary voluntary program to provide performance benchmarks for landscape design, construction and management. SITES addresses stormwater management, site disturbance, habitat protection and energy performance, among other parameters. http://www.sustainablesites.org/

U.S. Department of Agriculture Forest Service:UFORE Model

A computer model developed by the U.S. to quantify spatially-explicit urban forest structure and function. The model calculates multiple attributes related to urban ecosystem services including: air pollution, greenhouse gasses and energy use. http://www.nrs.fs.fed.us/tools/ufore/

U.S. City of Seattle, Washington: Green Area Factor

A scoring system to encourage the use of green infrastructure practices in new development to provide ecosystem services including: improving air quality, reducing stormwater, mitigating urban heat island effects, and creating wildlife habitat. http://www.seattle.gov/dpd/Permits/GreenFactor/Overview/

U.S. Environmental Protection Agency STAR Program

Science to Achieve Results Program (STAR), promotes research on the performance of green infrastructure at multiple scales. http://water.epa.gov/infrastructure/greeninfrastructure/gi_performance.cfm#databasesAndSummaryReports

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