Emerging Landscapes

Toward Ecosystem Services as a Basis for Design

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ABSTRACT Environmental design has a long history of concern for ecosystems but has often lacked explicit assessments of, or goals associated with, site performance. Ecosystem services provide an organizing concept around which to make a wide array of environmental and, to some extent, social design goals explicit. Additionally, they allow assessment and evaluation of site-design decisions through both pre-construction modeling and/or post-occupancy evaluation. The U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system and the Sustainable Sites Initiative (SITES) are used as examples of how performance-based site design can be incorporated into the design process. We suggest that the maintenance of ecosystem services become a standard and increasingly monitored goal for the practice of environmental design. This move toward performance goals linked to ecosystem services for which success or failure can be determined is essential if environmental design is to offer a substantive contribution to the achievement of a more sustainable culture.

KEYWORDS Sustainable design, Sustainable Sites Initiative, LEED, performance-based design, ecosystem services

ECOSYSTEM SERVICES AS THE BASIS FOR DESIGN GOALS

The practice of architecture, landscape architecture, and planning is increasingly challenged to become "more sustainable," a phrase now understood as achieving some balance of environmental quality, social equity, and economic efficiency. In effect, this imperative has largely been translated into efforts directed at the conservation of energy, water, and materials. The pursuit of sustainability, however, has been fragmented, as there is no real consensus about how "sustainability" exactly might be realized or measured. The concept of "ecosystem services" represents one way to make many environmental and economic, as well as some social, objectives explicit and measurable and thereby make greater and more coordinated progress toward a more sustainable culture. Although the framework that ecosystem services offer for identifying the often-overlooked values that humans derive from natural processes is not perfect, it does provide a conceptual way to clarify the importance of these services. Once such values are explicitly recognized and their performance tracked, environmental design will not only conserve valuable environmental resources but also provide solutions for the further production of those resources. In this way it may be possible to move beyond the "mere" sustenance of our current environmental capacity to the (re)generation of previously lost systemic capacity.

While concern for the effect of the environment on human life has been a constant within the field of environmental design, concern for the impact of our designs on ecosystems has gained significant attention only in the last 50 years. Individuals such as Ian McHarg (1969), John T. Lyle (1994), Kevin Lynch (with Gary Hack 1984), and others began in the early 1960s to incorporate a concern for the environment into design through the development of specific goals toward protecting those resources perceived or known to be ecologically significant.

McHarg's contributions include the identification and inclusion of explicit environmental information into the design and planning process as well as the use of ecology to organize that data. Through numerous projects, he illustrated how such a process could be employed to identify environmental impacts of proposed projects and to determine the suitability of various land uses. Lyle built on McHarg's ecological advocacy by proposing a regenerative approach for imperative design. Regenerative design is based on knowledge of ecosystems and on using that understanding to create healthy places. Meanwhile, Lynch codified the approach that most landscape architects, architects, and planners use for site planning and design.

More recently, William Thompson and Kim Sorvig (2000) have outlined 10 principles for further reducing the footprint of landscape design. Similarly, William McDonough and Michael Braungart (2002) have advocated going beyond resource conservation based on first use by including life-cycle costs in the design process. In fact, over the past two decades, an ever-increasing body of literature has advanced ecological design (Thompson and Steiner 1997; Van der Ryn and Cowen 2007), sustainable site design (Calkins 2009; Dinep and Schwab 2010; Russ 2009), green neighborhoods (Girling and Kellett 2002, 2005), and environmental design for human health (Jackson 2003).

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This awareness has increased the frequency with which environmental goals are incorporated in the design process. Less frequent but also increasing is any assessment of performance toward achieving goals established at the outset of design. With the rise of the desire to conserve energy (and, more recently, water), has brought about a significant increase in the modeling of mechanical systems to help assess design alternatives. The modeling of systems has, in turn, led to improved performance (Turner and Frankel 2008). While these efforts have left a significant mark on the practice of environmental design, they have at best focused on the wise use of finite resources. What has been missing is a method to consolidate environmental design efforts into larger ecological, economic, and social benefits both at the site level and beyond. Ecosystem services provide a conceptual model to describe these benefits and link them directly to the economic framework that governs development practice.

ECOSYSTEM SERVICES

Economists have adopted the term "ecosystem services" to describe benefits that the environment provides to humans at no cost, benefits we would have to provide for ourselves if our surroundings ceased to provide them (Costanza et al. 1997; Daily 1997; De Groot, Wilson, and Boumans 2002; Farber, Costanza, and Wilson 2002; Hirsch 2008). These services include the manufacture of critical "products" such as breathable air; fishable, swimmable, and drinkable water; cycling of atmospheric gases, nutrients, and waste; and a host of others, including benefits such as ecotourism, derived from the primary ecosystem services.

The United Nations in 2000 called for the creation of the Millennium Ecosystem Assessment (2005) so as "to assess the consequences of ecosystem change for human well-being and the scientific basis for actions needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being." The United Nations asserted not only that ecosystem services are a necessity for current and future quality of life and continued economic development but also that, unless we change the way that these services are considered in our economics and actions, they are unlikely to continue to meet our needs in the future: "At the heart of this assessment is a stark warning. Human activity is putting such strain on the natural functions of Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted" (Millennium Ecosystem Assessment 2005, 7).

Economists have begun to monetize ecosystem services so as to demonstrate the necessity of incorporating both the current diminishment and the potential enhancement of these services into our economic system (Costanza 2008). Such accounting for direct economic value derived from the environment is not necessarily a new concept. Widely accepted examples include the annual estimates of harvested natural resources that were long ago worked into systems of economic valuation. The concept of ecosystem services goes further, however, to include resources formerly taken for granted (such as clean air and water) and externalized from economic accounting.

The World Resources Institute (WRI 2008) has produced several publications aimed at providing a framework for public policy development around the concept of ecosystem services (including a formalized categorization of ecosystem services). These publications go beyond considering how practices and policies affect ecosystems to incorporate an understanding of how development is dependent upon ecosystems and the services they provide. The WRI proposes that planning go beyond protecting critical remaining ecosystems from the adverse consequences of development to managing these ecosystems to promote long-term sustainable development (WRI 2008).

EXAMPLES OF ECOSYSTEM SERVICES

The City of New York discovered the value of the services provided by the Catskill and Delaware watersheds when, beginning in 1989, the U.S. Environmental

Protection Agency (EPA), using the Safe Drinking Water Act, determined that increasing development in these watersheds threatened the quality of the water flowing from them. New York City's 9 million residents depend on these watersheds for 90 percent of their drinking-water supplies (Hirsch 2008). The city anticipated the need to construct a new drinking-water treatment plant costing $4 billion to $6 billion and an annual operating budget of $250 million (Appleton 2002), with recent cost estimates even higher. Instead of building the drinking-water treatment plant, the City of New York worked with the state and the communities in the Catskill and Delaware watersheds to create a sustainable development plan for the region. This plan not only emphasized where continued development was appropriate but also enabled New York City, beginning in the early 1990s, to purchase critical lands within the watershed so as to keep them from future development. By 1996, the city had spent $1.5 billion in land preservation, and the EPA agreed that the land acquisition (and the city's program to install low-flush toilets) had forestalled, and potentially eliminated, the need to construct a much-more-expensive water treatment plant (City of New York 1996). A 1997 Memorandum of Agreement signed by the City and State of New York, the EPA, 73 local municipalities, and 5 environmental organizations extended the efforts in land acquisition, watershed rules and regulations, and watershed protection and partnership programs (Pires 2004). In this case, the water-cleansing capacity of those lands provided the same services a drinking-water plant would have—at one-third the cost. The city and its watershed partners were able to develop a plan that allowed for development *and* water quality because they emphasized from the outset that performance in both of these areas was critical.

One example of the disastrous consequences of ignoring the services provided by natural systems comes from New Orleans and the devastation caused by Hurricane Katrina and the loss of coastal wetlands and marshes. In October 2004, almost a year before Hurricane Katrina came ashore, *National Geographic* published an article forecasting the damage that a Category 5 hurricane hitting New Orleans would cause. The article's author, Joel Bourne (2004), predicted the failure of the levies, the flooding of much of New Orleans, and the huge loss of life and property such a storm would cause. Additionally, Bourne pointed out that a storm surge associated with such a hurricane would cause much of this damage and that the repair and restoration of the region's coastal wetlands, marshes, estuaries, and thus of the ecosystem services they once provided, could significantly mitigate the damage. Not only does a healthy coastal landscape decrease the storm surge associated with hurricanes, it also provides the nursery for much of the aquatic life driving the fishing economy of the region—the second largest fishery in the nation and an economy hard hit by the loss of productive coastal systems. A study by the U.S. Army Corps of Engineers found that an investment of from $2 billion to $14 billion from 2004 and 2014 could repair this critical economic engine and so better protect New Orleans from future hurricanes (Bourne 2004). The effort was not funded, and in August 2005 Katrina, a mere Category 3 hurricane, devastated much of the Louisiana and Mississippi coasts, causing the greatest loss of human life and property due to a natural disaster in U.S. history. By 2006, the Bush administration had sought $105 billion for repairs and reconstruction in the region (St. Onge and Epstein 2006), and the U.S. Gulf Coast from Florida to Texas still remains vulnerable to hurricanes (Steiner et al. 2006), as illustrated by the impact of Hurricane Ike on Galveston in 2008.

Ecosystem services are not, however, produced only by pristine wilderness areas far from urban centers. Although some ecosystem functions are limited by landscape size and continuity, many are not. Where the mechanisms are independent of scale and extent, urban landscapes may contribute significantly to regional ecosystem function. Moreover, the negative environmental impacts in urban landscapes are often more acute than those experienced in nonurban settings. Thus, the value of addressing ecosystem service issues where they originate and affect the largest populations—urban centers—is increased. Urban sites

Figure 1. Rain garden implemented at the site perimeter at the Pearl Brewery redevelopment in downtown San Antonio, Texas, sufficient to ensure percolation of rain runoff. Design team included Rialto Studio, Lake|Flato Architects, Sprinkle & Company Architects, Three Architecture, Pape-Dawson Engineers, and Danysh & Associates Structural Engineers (Photo courtesy of Rialto Studio).

may easily be designed to provide specific ecosystem services, such as the reduction of the local heat-island effect; the reduction of stormwater runoff and improvement of the quality of that runoff; improved air quality, particularly related to reductions in surface ozone and particulates; and improved visual and physical access to green space, an increasingly recognized component of a livable city (Kaplan 2007; Kuo 2001; Ulrich et al. 1991). On the high-technology end, society may spend significant sums to outfit structures with photovoltaic arrays to generate electricity, but it may also more simply and cheaply use street trees to reduce energy demand through direct shading and reduction of the local ambient temperature, resulting in two to five times the return on initial investment (Peper et al. 2007). Likely we will need high-technology approaches as well as basic efforts at reducing demand and producing basic ecosystem services. Too often these more basic parts of the solution are overlooked in favor of more novel and expensive technological approaches.

The U.S. Department of Agriculture Center for Urban Forest Research has calculated the economic value of trees in urban centers across the United States. In New York, the economic value in terms of reduced stormwater and energy costs as well as increased property values is measured in the millions of dollars annually. For every dollar spent on the planting, care, and maintenance of New York's trees, $5.60 of value is generated. While this rate of return is the highest found in any analysis, other studies have found a significantly positive return on investment: Fort Collins, Colorado ($2.18); Glendale, Arizona ($2.41); and Charlotte, North Carolina ($3.25) (Peper et al. 2007). These values do not include the benefit of the carbon sequestration offered by these urban trees, estimated for the entire United States at approximately 25 million tons of carbon per year (Nowak and Crane 2002).

Urban trees are only the start of what we can do to produce ecosystem services in urban environments. When properly designed, features such as utility corridors, parks, green roofs, green walls, stormwater wetlands, rain gardens, and even raptor perches provide valuable ecosystem services to our communities (Figure 1).

CRITIQUE OF THE ECOSYSTEM SERVICES CONCEPT

We can incorporate the production of ecosystem services as explicit goals in the practice of environmental design, but there are significant challenges to the assumption that such services can be monetized. Not every ecosystem service can be evaluated economically with accuracy, and our inability to do so often results in the undervaluation of services. The values of many finite resources tend toward infinity as they are depleted. At the other extreme, it is nearly impossible to set a non-arbitrary financial value on the waste-cycling services provided by a single microorganism living in the soil. The loss of a single micro-organism can result in a loss of ecosystem services, but the complexity of biotic and abiotic processes involved means that it is difficult to assess how critical this loss is before the loss occurs. For example, historic and prehistoric evidence suggests that the regional loss or decline of a single species either causes significant or catastrophic human impacts (the 19th-century Irish potato famine and the extinction of the Rapa Nui palm, *Paschalococos disperta,* on Easter Island) or has no significant human impact at all (the Mauritius dodo). The loss of a functionally redundant species within an ecosystem is significantly different from the loss of a critical "keystone" species (Naeem and Li 1997; Walker 1992). Nevertheless, placement of an organism in either category, or somewhere on the continuum, is difficult because of the complex web of interactions among species. Because of this complexity the analysis of individual ecological components such as biodiversity may result in an inaccurate assessment of function.

The concept of ecosystem services sidesteps this problem by evaluating the economic value of products (or the processes that produce those products) rather than the components themselves. By their own admission and others' assessment (for example, Opschoor 1998), however, Costanza and his colleagues' (1997) estimates of economic value rely on multiple sources of potential error. The Costanza assessment ignores infrastructure value, change in value over time, and interactions among ecosystem services. It assumes sustainable use and lack of critical thresholds and is a snapshot of values based on the willingness to pay for multiple products or processes at a given time. While the concept of ecosystem services is useful in decision making, it requires constant reevaluation to be even roughly accurate, as price curves may become steep as supply diminishes.

While the limitations of applying an economic value to a given service are evident, the strength of the ecosystem service concept lies in its identification and quantification of specific products and its description of the processes and essential components that maintain them. This creates three opportunities for scientists, planners, and designers:

1. Scientists must more effectively measure and model the processes required to produce ecosystem services, so that these critical components can be incorporated into specific design applications.
2. Regional planners or policymakers need to identify regional priorities for ecosystem services production based on current or predicted requirements.
3. Designers should ensure that their design features integrate the processes and components essential to provide appropriate levels of priority ecosystem services. Priority ecosystem services could either be identified from specific needs at the site level, or from larger regional needs or goals.

For example, the negative correlation between ozone concentrations and living, vegetative biomass suggests that increasing green-leaf area in urban centers should be maximized. This proposition has been quantified by models suggesting that leaves affect ozone concentrations both through dry deposition and the alteration of local climate. Increasing urban tree cover from 20 to 40 percent has reduced daytime ozone concentrations in models by 2.4 percent (Nowak et al. 2000). At the scale of a city, a 2.4 percent reduction might be enough to bring air quality within federally mandated limits, thus avoiding penalties. The benefits of this finding alone could provide an economic incentive large enough to justify the implementation of citywide tree-planting programs without consideration of the effects of air-quality improvement on human health and quality of life or an assessment of the indirect value of increasing tree cover (more shade, lower heat-island effect). Even design approaches focusing on a single ecosystem service might lend themselves to a more holistic design approach because many natural processes (for example, photosynthesis) support multiple services (for example, oxygen production, carbon sequestration, and improved air quality).

Figure 2. Green-roof research plots at the Lady Bird Johnson Wildflower Center, Austin, Texas. The study found significant differences in performance in terms of plant success, quality of water runoff, and water-detention capacity among six green-roof manufacturers (Photo by Mark Simmons).

Focusing on a single ecosystem service, however, may also have unintended negative consequences. There may be trade-offs in maximizing a single ecosystem service where optimization of multiple ecosystem services is the overriding goal. With the urban-tree example, variation exists in the removal of air pollutants by specific species as well as in the total amount of pollution, length of in-leaf season, precipitation, and other climatic variables (McPherson et al. 1994; Nowak et al. 2000; Smith 1990). A singular focus on this one goal without adequate information included in estimates could result in lower than predicted performance or lead to the maximization of atmospheric-pollution reduction at the expense of biological diversity and wildlife values, as well as of aesthetic or other social concerns. So while we may expect ecosystem services not to be mutually exclusive—improving one attribute often improves others—maximizing one service without regard to other services may not optimize overall ecosystem-services production. For optimal performance, this approach must be measured or modeled in specific instances and directly related to specific performance goals.

Awareness of the multiple ecosystem services associated with a specific practice could, however, open up a much broader array of values for a specific project at different spatial scales and ranges of political objectives. At a national level, regulating services such as carbon sequestration might rank highly and so result in incentives (or penalties). At the level of state or region, supporting services (for example, crop pollination) might be employed to support agriculture. A city might consider efforts aimed at reduced peak-stormwater-discharge rates most beneficial, while at the site level the user might place priority on cultural services such as recreational benefits. It is entirely possible that a single practice, such as high-productivity rain gardens designed to also provide pollinator habitat, would enhance all these goals.

A final risk in setting goals associated with ecosystem services is the difficulty of the direct measurement of many of these services, as well as the ease with which it may appear that goals have been met. For many practices, actual performance in specific applications is rarely assessed. As an example, many cities across the United States, most notably Chicago, have provided incentives for the establishment of green roofs on buildings, citing benefits to air and water quality as well as reductions in heat-island effect. At least one study has shown that not all green roofs provide the same benefits, and some might provide no benefit at all (Simmons et al. 2008, Figure 2). Merely incentivizing a specific practice without focus on specific or multiple performance goals—or judging the attainment of goals without quantitative or qualitative evaluation—runs the risk of not achieving the benefits a practice is meant to provide.

Figure 3. The middle school at Sidwell Friends School in Washington, D.C., is a LEED-certified building at a Platinum level, having incorporated significant ecological elements into the design. Pictured is a view from the top of the wetland terrace towards the new extension of the Middle School building. The design team included Kieran Timberlake Associates, Andropogon Associates, and Natural Systems International (Photo courtesy of Andropogon Associates).

LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN

The incorporation of quantitative and qualitative assessment of performance into design gained wider acceptance beginning with use of the U.S. Green Building Council's (USGBC's) Leadership in Energy and Environmental Design (LEED) rating system. This tool aims to encourage the attainment of specific performance goals through voluntary efforts to achieve specific "credits." The initial LEED rating system was released in 2000 as a standard for new building construction. It offers four levels of certification—certified, silver, gold, and platinum—depending on how many credits a project accrues within six categories (USGBC 2009b):

1. sustainable sites
2. water efficiency
3. energy and atmosphere
4. materials and resources
5. indoor air-quality innovations
6. design process.

The Sidwell Friends School in Washington, D.C., is an example of a building that has achieved Platinum LEED certification (Figure 3). The LEED program also involves an accreditation program for professionals "driving ongoing excellence in green building practice" (Green Building Certification Institute 2010).

From its early focus on new construction, LEED has expanded to address major renovation projects, improved performance from existing buildings, commercial interiors, homes, neighborhoods, campuses, schools, and retail spaces. One of the most recent LEED tools, LEED for Neighborhood Development, is the result of collaboration among the USGBC, the Natural Resources Defense Council, and the Congress for the New Urbanism. This rating system "integrates the principles of smart growth, urbanism and green building into the first national standard for neighborhood design" (USGBC 2009a)

LEED tools tie an increasing number of the credits explicitly to building performance. Credits are awarded for specific achievement levels for areas such as energy and water conservation and percentages of recycled products used or recycled from the job site. As the tools identify performance categories and achievement levels in advance, the project team must consider explicit goals during the design process and discuss those areas where the practice of one discipline adversely affects the achievement of performance levels in others. This necessarily promotes integrated design teams. A design issue such as ensuring adequate interior daylight also affects heating and cooling requirements, window glazing, mechanical lighting levels, interior elements such as light shelves, and exterior landscape choices. In this way, explicit performance-based goals and integrated design teams ensure the design of structures intended to perform at higher levels than those building designs lacking explicit performance goals. The lack of clear goals is one of the risks LEED associates with "silo-based" design teams.

Treating rating systems such as LEED as ends in themselves, however, may cause significant problems. The New Buildings Institute conducted a study (Turner and Frankel 2008) quantifying the energy performance of 121 LEED New Construction buildings across the country that had been occupied for at least one year (22 percent of the total number of buildings certified by LEED and meeting occupancy requirements). Overall, the results were positive. The institute found that the median energy use for the certified LEED buildings tested was 24 percent less than for non-LEED buildings. LEED-certified office buildings (the largest category of LEED-certified buildings) had a median Energy Use Intensity 33 percent lower than that of noncertified offices. That said, a number of individual LEED-certified buildings turned out to be poor performers, with 25 percent of the buildings reviewed using more energy than average for comparable noncertified building stock (Turner and Frankel 2008). This may in part be a result of the fact that many LEED-awarded credits, particularly in its early versions, were not tied to energy performance and were often less expensive to incorporate than changes in mechanical systems. Even within energy-performance categories, there was wide variation in the credits per gigajoules of energy conserved, and the credits with the most impact were 2600 percent more effective than the least (Scheuer and Keoliean 2002). Projects pursuing the least expensive way to accumulate credits, rather than the most effective way to reduce energy, were likely to result in buildings that scored well with LEED but did not perform as the designers of the rating system wanted. This is not surprising: when the goal becomes final certification level rather than building performance, the resulting design decisions may not prove to be sustainable.

Given the range of pressing concerns, it seems prudent to incorporate a larger range of measurable performance-based goals associated with ecological health into the practice of environmental design. To some extent, this larger agenda has already been initiated. For example, because of LEED, concern for indoor environmental quality has risen sharply. In a broader sense, through initiatives like LEED and Architecture 2030 (Architecture 2030 2007), building architects are seeking to conserve energy and thereby reduce demands on the fossil fuels contributing significantly to many pollution problems. It is possible, however, to go beyond using environmental design to provide for the mere conservation and efficient use of resources—to use design to generate increased environmental capacity through the production of ecosystem services.

INCORPORATING ECOSYSTEM SERVICES INTO DESIGN GOALS

The maintenance of ecosystem services—particularly those identified by the site or region as critical—must become a core practice of environmental design. In so doing, we must focus on services that can be valued or assessed, preferably in a quantifiable manner, or at least in such as way that the direction of change may be determined, and the "product" of those services may be monitored over time. Other, more qualitative, benefits affected by these quantifiable services must at a minimum be identified as positively or negatively affected.

In this way, the concept of ecosystem services may be used to identify processes and products deemed important or essential and to provide a framework around which we may create a short list of performance goals for particular sites. The list of performance goals must remain flexible to allow updates and regional adaptation. There are many ecosystem services with poorly or even moderately understood mechanisms, which are thus difficult to evaluate and that fall short of eligibility of the criteria outlined above (for example, localized heat-island effect and flora and fauna metapopulation dynamics). Identifying ecosystem services not currently quantified that might contribute significantly to whole landscape performance represents a critical need for further research and modeling.

The bulk of the work in developing planning policy surrounding ecosystem services, for organizations such as the Millennium Ecosystem Assessment and the World Resources Institute, focuses on the preservation of natural systems so that these can continue to provide essential ecosystem services. The preservation of remaining systems is, of course, critical to ensuring that the world's ecosystems have the capacity to continue to provide the goods and services we require for human life. But preservation alone is not enough. To go beyond reliance on remaining intact ecosystems, others have focused on altering the practice and function of large-scale rural systems (Entry, Soika, and Shewmaker 2002). This, however, because of economic restrictions on both scale and availability, may prove infeasible in many areas or carry large ecological risks resulting from the large-scale modification of critical landscape processes (Palmer and Filoso 2009). Conversely, focusing on the designed environment, particularly in urban and suburban areas, represents a great opportunity to improve ecological performance as part of the existing design process with significantly less risk as the scale of any one intervention is significantly smaller. In these locations, modification of the environment is often already underway and the necessary economic drivers are present in the waste streams (such as stormwater and nutrients) that might be converted to beneficial use; there is also great potential for raising public awareness and education levels surrounding the sustainable use of resources. As global populations continue to grow, our challenge is to create—or re-create—communities that ensure the maintenance and enhancement of ecosystem services through development processes.

THE SUSTAINABLE SITES INITIATIVE

The Sustainable Sites Initiative (SITES 2009) represents an attempt to provide performance-based guidelines for the maintenance, and in some cases regeneration, of ecosystem services. Modeled after the USGBC's LEED rating system, SITES is a set of voluntary guidelines for development focused on the building-skin outward, or on projects without a building at all. SITES—led by the Lady Bird Johnson Wildflower Center at The University of Texas at Austin, the American Society of Landscape Architects, and the United States Botanic Garden—focuses not only on plugging a perceived gap in the existing LEED rating system for dealing with site-based issues but also on going beyond conservation toward the conscious generation of ecosystem services as part of the design process. Through the 51 credits and 15 prerequisites (Table 1) contained in *The Sustainable Sites Initiative Guidelines and Performance Benchmarks 2009*, SITES seeks to make performance-based explicit.

This approach, when combined with efforts like LEED, offers designers the tools necessary to set specific goals surrounding the conservation and regeneration of a broad array of ecosystem services. SITES focuses on the following 12 often-overlapping ecosystem services:

1. global climate regulation
2. local climate regulation
3. air and water cleansing
4. water supply and regulation
5. erosion and sediment control
6. hazard mitigation
7. pollination
8. habitat functions
9. waste decomposition and treatment
10. human health and well-being benefits
11. food and renewable nonfood products
12. cultural benefits

Of the 66 prerequisites and credits, roughly 60 percent tie quantitative measures of performance to credit achievement, while the other 40 percent are primarily prescriptive in nature; all attempt to tie credit attainment with ecosystem services production.

The credits vary significantly in terms of requiring performance attainment. Of the 39 credits that set quantitative levels of performance, the bulk remain

Table 1. List of SITES Prerequisites and Credits along with the potential point value associated with each credit.

Section 1: Site Selection	**21 possible points**
Prerequisite 1.1: Limit development of soils designated as prime farmland, unique farmland, and farmland of statewide importance	
Prerequisite 1.2: Protect floodplain functions	
Prerequisite 1.3: Preserve wetlands	
Prerequisite 1.4: Preserve threatened or endangered species and their habitats	
Credit 1.5: Select brownfields or greyfields for redevelopment	5–10 points
Credit 1.6: Select sites within existing communities	6 points
Credit 1.7: Select sites that encourage non-motorized transportation and use of public transit	5 points
Section 2: Pre-Design Assessment and Planning	**4 possible points**
Prerequisite 2.1: Conduct a pre-design site assessment and explore opportunities for site sustainability	
Prerequisite 2.2: Use an integrated site development process	
Credit 2.3: Engage users and other stakeholders in site design	4 points
Section 3: Site Design—Water	**44 possible points**
Prerequisite 3.1: Reduce potable water use for landscape irrigation by 50 percent from established baseline	
Credit 3.2: Reduce potable water use for landscape irrigation by 75 percent or more from established baseline	2-5 points
Credit 3.3: Protect and restore riparian, wetland, and shoreline buffers	3–8 points
Credit 3.4: Rehabilitate lost streams, wetlands, and shorelines	2–5 points
Credit 3.5: Manage stormwater on site	5–10 points
Credit 3.6: Protect and enhance on-site water resources and receiving water quality	3–9 points
Credit 3.7: Design rainwater/stormwater features to provide a landscape amenity	1–3 points
Credit 3.8: Maintain water features to conserve water and other resources	1–4 points
Section 4. Site Design—Soil and Vegetation	**51 possible points**
Prerequisite 4.1: Control and manage known invasive plants found on site	
Prerequisite 4.2: Use appropriate, non-invasive plants	
Prerequisite 4.3: Create a soil management plan	
Credit 4.4: Minimize soil disturbance in design and construction	6 points
Credit 4.5: Preserve all vegetation designated as special status	5 points
Credit 4.6: Preserve or restore appropriate plant biomass on site	3–8 points
Credit 4.7: Use native plants	1–4 points
Credit 4.8: Preserve plant communities native to the ecoregion	2–6 points
Credit 4.9: Restore plant communities native to the ecoregion	1–5 points
Credit 4.10: Use vegetation to minimize building heating requirements	2–4 points
Credit 4.11: Use vegetation to minimize building cooling requirements	2–5 points
Credit 4.12: Reduce urban heat island effects	3–5 points
Credit 4.13: Reduce the risk of catastrophic wildfire	3 points
Section 5: Site Design—Materials Selection	**36 possible points**
Prerequisite 5.1: Eliminate the use of wood from threatened tree species	
Credit 5.2: Maintain on-site structures, hardscape, and landscape amenities	1–4 points
Credit 5.3: Design for deconstruction and disassembly	1–3 points
Credit 5.4: Reuse salvaged materials and plants	2–4 points
Credit 5.5: Use recycled content materials	2–4 points
Credit 5.6: Use certified wood	1–4 points
Credit 5.7: Use regional materials	2–6 points
Credit 5.8: Use adhesives, sealants, paints, and coatings with reduced VOC emissions	2 points
Credit 5.9: Support sustainable practices in plant production	3 points
Credit 5.10: Support sustainable practices in materials manufacturing	3–6 points

(*continued*)

Table 1 (*continued*)

Section 6: Site Design—Human Health and Well-Being	**32 possible points**
Credit 6.1: Promote equitable site development	1–3 points
Credit 6.2: Promote equitable site use	1–4 points
Credit 6.3: Promote sustainability awareness and education	2–4 points
Credit 6.4: Protect and maintain unique cultural and historical places	2–4 points
Credit 6.5: Provide for optimum site accessibility, safety, and wayfinding	3 points
Credit 6.6: Provide opportunities for outdoor physical activity	4–5 points
Credit 6.7: Provide views of vegetation and quiet outdoor spaces for mental restoration	3–4 points
Credit 6.8: Provide outdoor spaces for social interaction	3 points
Credit 6.9: Reduce light pollution	2 points
Section 7: Construction	**21 possible points**
Prerequisite 7.1: Control and retain construction pollutants	
Prerequisite 7.2: Restore soils disturbed during construction	
Credit 7.3: Restore soils disturbed by previous development	2–8 points
Credit 7.4: Divert construction and demolition materials from disposal	3–5 points
Credit 7.5: Reuse or recycle vegetation, rocks, and soil generated during construction	3–5 points
Credit 7.6: Minimize generation of greenhouse gas emissions and exposure to localized air pollutants during construction	1–3 points
Section 8: Operations and Maintenance	**23 possible points**
Prerequisite 8.1: Plan for sustainable site maintenance	
Prerequisite 8.2: Provide for storage and collection of recyclables	
Credit 8.3: Recycle organic matter generated during site operations and maintenance	2–6 points
Credit 8.4: Reduce outdoor energy consumption for all landscape and exterior operations	1–4 points
Credit 8.5: Use renewable sources for landscape electricity needs	2–3 points
Credit 8.6: Minimize exposure to environmental tobacco smoke	1–2 points
Credit 8.7: Minimize generation of greenhouse gases and exposure to localized air pollutants during landscape maintenance activities	1–4 points
Credit 8.8: Reduce emissions and promote the use of fuel-efficient vehicles	4 points
Section 9: Monitoring and Innovation	**18 possible points**
Credit 9.1: Monitor performance of sustainable design practices	10 points
Credit 9.2: Innovation in site design	8 points

prescriptive in method, with only 7 (21 percent) allowing for open-ended attainment of those performance levels. One example of a high-performance-based credit: "Manage stormwater on site" (credit 3.5) provides a method for comparing regionally adjusted, model runoff-curve numbers for pre- and post-development conditions and sets different point values based on preservation or reduction of runoff volumes. This type of credit leaves the determination of how to achieve performance levels to the design team. The designers may choose to incorporate conventional stormwater approaches such as detention ponds or low-impact design approaches such as rain gardens (Figure 4), rainwater harvesting, or green roofs, so long as the combination of methods used may be shown through modeling to meet the performance goal.

The SITES credits move beyond conservation to the restoration of resources through credits such as "preserve or restore appropriate plant biomass on site" (credit 4.6). This credit ensures regionally appropriate levels of vegetation (referred to as Biomass Density Index or BDI) be maintained or established on site. Maintaining regionally appropriate levels of vegetative cover is a critical component for the production of many ecosystem services. Like many credits, the required performance level required varies based on the type of site. For "greenfield" areas—those never previously developed—post-development BDI levels must at a minimum equal historic predevelopment conditions. For greyfield or brownfield sites that have lost significant levels of vegetation through earlier development, the credit provides a greater array of points based on increasing BDI levels through the amount of vegetation incorporated into the new site design. Post-construction vegetation amounts are estimates based on cover type after 10 years of growth and compared to appropriate region-specific

Figure 4. A series of bioretention cells captures and treats stormwater on site at the John Burroughs School in Laude, Missouri. Design team included Christner, Intuition and Logic, Volz, and John Burroughs School (Photo courtesy of John Burroughs School).

vegetation levels based on climate and dominant habitat types. How these BDI levels are attained is left to the design team, but they may include everything from preserving existing areas of high-quality vegetation to creating dense, highly formal gardens, to incorporating green walls and roofs, to some combination of several approaches.

Most SITES credits are achieved in relation to predicted performance, and there is still no effective way to evaluate quantitatively the ecosystem services produced by the achieved credits. In an attempt to address this, SITES, like the most recent versions of LEED, has added credits associated with monitoring performance and, perhaps most importantly, with reporting this information in peer-reviewed journals and professional magazines. It is unclear as to how frequently this relatively high-valued credit (worth 10 percent of minimum certification levels) will be pursued, as it requires from 6 months to 10 years worth of data (depending on the specific credit monitored). As a result, this approach is still only a first step in the incorporation of ecosystem services into design goals within the built environment. Environmental design clearly needs greater emphasis on assessment.

PERFORMANCE ASSESSMENT

Attaining specific performance levels drives design; their attainment is tested after construction or modeled in advance for a specific application. Examples include performance in areas such as daylighting, cooling patterns, general energy usage in buildings, as well as on-site patterns of hydrologic flow and water quality. This approach sets attainment of target performance levels ahead of specific technology and is more likely to encourage innovation and solutions adapted to specific site conditions. Making project performance goals explicit and assessable (or directly measurable) from the outset challenges even the clients to think about secondary goals they likely hold but have not made explicit. Additionally, a project is more likely to achieve all, or at least a greater percentage of its goals when they are made explicit from the outset of design. For example, a primary goal could broaden from constructing a building to house 50 employees to one that meets housing needs while reducing operating costs by 35 percent through resource efficiency, reduces the number of employee sick days by 10 percent, lowers health care costs by 15 percent, improves air quality by reducing particulate concentrations in the building and in occupied outdoor spaces by 30 percent, and increases site-based stormwater infiltration by 20 percent over the current condition to provide base flow to a local creek. In each case, these performance goals, whether in the building or the landscape, may be modeled during, and in many cases directly monitored after, construction.

While stormwater modeling in the landscape is well established and pre-construction modeling for building performance has become more common, direct monitoring for post-construction effectiveness in these areas is less so. This lack of monitoring is undoubtedly due to the associated costs, as well as to the perceived consequences of failure to careers or to potential legal action. As we increasingly rely on pre-construction modeling as a way to evaluate performance, these models must be field-tested with greater regularity to ensure proper application and further refinement. This protocol is perhaps more critical for environmental design than for other disciplines because of the heavy reliance on "case studies" in the training and practice of design.

While the term "case study" is too often applied to "war stories," there is an effective and established formal method that, if applied more frequently, would significantly improve design practice. McHarg (1969) used a series of professional and student projects to illustrate his "design with nature" theory. More recently, Duchhart (2007) has used two decades of experience in Kenya to develop a theory for environmental design for Africa. Researchers such as Yin (2003, 2009) have adapted more rigorous approaches for case-study research from business, law, and the social sciences.

As a result of the recognition for need of more rigorously defining case-study research for environmental design, the Landscape Architecture Foundation commissioned Mark Francis (2001) to develop a case-study method for landscape architecture. Francis defines a case study as "a well-documented and systematic examination of the process, decision-making, and outcomes of a project, which is undertaken for the purpose of informing future projects, policy, theory, and / or education" (2001, 16). His method is widely applied in landscape architecture and landscape planning (see, for example, Ahern, Leduc, and York 2007; Francis 2003a, 2003b; Hou, Johnson, and Lawson 2009; Schneider 2003). More frequent and rigorous post-occupancy case studies with performance monitoring will help build a body of knowledge for use in further refining a wide variety of predictive models and call attention to areas where more research is needed.

A more rigorous use of case studies and post-occupancy evaluation of design will allow for increasingly "adaptive design." Adaptive management is an approach to conservation where clearly defined goals are set for a given project based on quantitative models and simulations. Monitoring is put in place to assess actual progress towards achievement of the goals and the environmental management is modified over time to improve performance based on further modeling refined by actual results seen in the field (Schreiber 2004). This same approach can be put in place for environmental design where rigorous case studies and post occupancy evaluation are used to refine our models predicting performance and improve actual performance of future designs.

DIRECTIONS FOR FUTURE RESEARCH AND PRACTICE

A number of research issues must be addressed so as to design sites providing significant levels of ecosystem services. Current programs, such as LEED and SITES, provide explicit performance-based design goals, but these are only infrequently monitored to verify modeled predictions of performance. Only a few ecosystem services include models for predicting performance, and even fewer have been adequately confirmed with on-site monitoring. To ensure the ability to design sites that increase the capacity of local environments to provide ecosystem services, we must develop greater understanding of how to assess ecosystem-services production in both absolute and relative terms. In the meantime, a qualitative connection of project goals with larger ecosystem services made by appropriate professionals on a case-by-case basis is likely to help environmental design practitioners improve performance of site design in this regard. Simply establishing a qualitative connection between design and production of ecosystem services challenges the status quo on several levels, however:

- Environmental designers such as architects, landscape architects, and engineers must incorporate multidisciplinary teams to optimize multiple performance goals during site assessment, design, construction, and post-construction phases. Projects must begin with explicit identification of the ecosystem services a site must provide and with accordingly appropriate structure of the design team. SITES (2009) provides one framework for working through this process. Refinement of other existing techniques, such as Geographic Information Systems and environmental impact analysis, can provide additional ways in which to consider the effects of design on larger ecosystem services. Monitoring actual site performance toward attainment of these goals will allow for both adaptive management on those sites already constructed as well as adaptive design to improve models and future design practice.

- Planning authorities must move away from focusing on performance goals in isolation and facilitate efforts to achieve multiple environmental goals. These efforts must begin with the identification and ranking of ecosystem services critical to the particular city or region. Planning and regulatory policies and basic municipal codes relevant to the desired services must be identified, and appropriate incentives (and penalties) must be put in place to reward design which provides ecosystem services for public benefit. Additionally, regional planners must identify the types of models that will help to quantify landscape performance and communicate the need for such models to researchers.
- Researchers must focus on the quantification of ecosystem services or effective surrogates and begin to test practices with respect to multiple, cross-disciplinary, performance objectives. Additionally, models predicting performance of specific techniques must incorporate greater levels of field verification and calibration. More than anything else, researchers must make a greater effort to link research to applied design, work with designers and planners to identify potential design features which could incorporate the ecological processes critical to ecosystem services, and field-test the models predicting performance of these design elements. Because the majority of projects constructed will not be able to afford rigorous monitoring, these models must better consider the variables determining performance. Researchers must actively look for the applications and systemic modeling that will provide practitioners at least crude assessments of multiple ecosystem services and thus enable more informed decision-making.
- Funding agencies and regulators must increasingly request (and likely pay for) post-occupancy evaluation and general monitoring of performance goals so as to improve the ability of the built environment to attain the ecosystem-service performance levels desirable.

Further, the relatively crisp lines drawn between the design-and-construction phase and the operation-and-maintenance phase of a site must significantly blur, which has implications for not only the design construction and maintenance industry, but also potentially for regulators. Achieving the performance goals associated with ecosystem services may require as much attention to long-term management as to initial design. Rather than relying on the design of sites with the highest level of performance at installation (as is the case with most mechanical systems), landscape-based systems must be designed to provide ecosystem services that will often require maturation after installation to achieve desired design parameters and greater attention to maintenance processes as part of the design. Increasingly, if rating systems such as LEED and SITES are truly to improve sustainability, they must have a greater impact not only on design but also on site operations and management.

Incorporating ecosystem services as explicit guidelines in the design process will aid in the development of truly sustainable communities. We hold out the goal of designing the built environment in such a way as to retain and even enhance critical ecosystem services through the development process. To strive for less will leave our culture on the edge of crisis. Achieving this goal, however, may begin the reverse of many of the negative changes development has caused in the last century.

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