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Introduction to Ecological Landscaping: A Holistic Description and Framework to Guide the Study and Management of Urban Landscape Parcels

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Introduction to Ecological Landscaping: A Holistic Description and Framework to Guide the Study and Management of Urban Landscape Parcels

Urbanized ecosystems and urban human populations are expanding around the world with potentially negative environmental outcomes. A challenge for achieving sustainable urban social-ecological systems is understanding how urbanized landscapes can be designed and managed to minimize negative effects. To this end, an interdisciplinary Ecological Landscaping conference was organized to examine the interacting sociocultural and ecological causes and consequences of landscaping practices and products. A theme of the conference was that scientific principles are important for guiding the development of sustainable landscaping practices and the public policies. To introduce this special issue of *Cities and the Environment* which contains articles from that conference, this paper describes the meaning of ecological landscaping and a conceptual framework that helps organize discussion of the topic's complex issues. The essence of ecological landscaping is a holistic systems-thinking perspective for understanding the interrelationships among many physical-ecological and sociocultural variables that give rise to the patterns and processes of biodiversity, abiotic conditions and ecosystem processes in urbanized ecosystems. This perspective suggests that 1) variables not considered part of traditional landscaping and 2) the effects of landscaping within an individual parcel on variables outside of it must both be considered when making design and management decisions. To illustrate how these points help create a more holistic, ecological approach to landscaping, an ecosystem model is used to create a framework for discussing how sociocultural and physical-ecological inputs to a landscape parcel affect its characteristics and the outputs leaving it. As exemplified by papers in this issue, an integrated sociocultural-ecological approach to the study of urban landscaping practices and products is needed to describe 1) why and how humans design and manage urban landscape parcels, 2) how the collective characteristics and outputs of many parcels give rise to the emergent ecosystem properties of urbanized areas and 3) the importance of educational programs for effecting sustainable landscaping choices. We conclude our paper by discussing the challenges for the future of ecological landscaping research and practice and a list of preliminary ecological landscaping guidelines. We hope that ideas in our paper and this special issue will increase understanding, visibility and research about the value of an ecological approach to landscaping.

Keywords

landscaping, urban ecology, systems thinking, sociocultural variables, landscape design, lawns, gardens

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Loren B. Byrne and Parwinder Grewal

Abstract

Urbanized ecosystems and urban human populations are expanding around the world causing many negative environmental effects. A challenge for achieving sustainable urban social-ecological systems is understanding how urbanized landscapes can be designed and managed to minimize negative outcomes. To this end, an interdisciplinary Ecological Landscaping conference was organized to examine the interacting sociocultural and ecological causes and consequences of landscaping practices and products. This special issue of *Cities and the Environment* contains a diverse set of articles arising from that conference. In this introductory paper, we describe the meaning of ecological landscaping and a new conceptual framework that helps organize the topic's complex issues. The essence of ecological landscaping is a holistic systems-thinking perspective for understanding the interrelationships among physical-ecological and sociocultural variables that give rise to the patterns and processes of biodiversity, abiotic conditions, and ecosystem processes within and among individually-managed urban landscape parcels. This perspective suggests that 1) variables not considered part of traditional landscaping and 2) the effects of landscaping within an individual parcel on variables outside of it must both be considered when making design and management decisions about a parcel. To illustrate how these points help create a more holistic, ecological approach to landscaping, a traditional ecosystem model is used to create a framework for discussing how sociocultural and physical-ecological inputs to a landscape parcel affect its characteristics and outputs. As exemplified by papers in this issue, an integrated sociocultural-ecological approach to the study of urban landscaping practices and products is needed to 1) understand why and how humans design and manage urban landscape parcels, 2) describe how the combined characteristics and outputs of many parcels give rise to the emergent ecosystem properties of urbanized areas, and 3) develop effective educational programs that catalyze adoption of sustainable landscaping choices and practices. The paper concludes with a discussion of challenges for the future of ecological landscaping research and practice, and a list of preliminary guidelines for ecological landscaping. We hope that this special issue will increase understanding, visibility, and research about the value of an ecological approach to urban landscaping.

Keywords

Ecological landscaping; urban ecology; systems thinking; sociocultural variables; landscape design; lawns; gardens.

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INTRODUCTION

In the U.S., more than 80% of the population resides, works, and plays in environments intentionally created and managed by humans (United Nations 2007). These human-dominated urbanized environments are characterized by horizontal and vertical impervious surfaces surrounded by lawns, scattered trees, and other ornamental vegetation. Management of urbanized landscapes is mostly aimed at maintaining roads, plants, and other structures in desired forms and spatial patterns. Although these points may be self evident, probably few of us reflect on them critically; instead, for most people, continued urbanization and typical landscape management practices are unquestioned social norms, to be accepted at face value rather than critiqued. It is only when something out of the “norm” occurs—a new type of residential development appears or a suburban lawn is replaced with a prairie—that people tend to reflect on their expectations about how urbanized landscapes should look and function, both socioculturally and ecologically.

In recent years, however, the design, management, and social-ecological dynamics of urbanized environments have been examined more critically by scientists, landscape architects, engineers, planners, policy makers, and concerned citizens. As a result, knowledge and awareness are increasing about the unintended, often negative, environmental effects caused by urbanization and certain landscape management practices (Grimm et al. 2008). To reduce or mitigate these negative effects, efforts have been made to develop new perspectives and strategies for more ecologically-informed approaches to urban landscape design and management (Smith et al. 2007; Tallamy 2007; Ecological Landscaping Association 2008; National Wildlife Federation 2008; Sustainable Sites Initiative 2008). These efforts provided the focus for a conference entitled “Ecological landscaping: From scientific principles to public practices and policies” held in October 2007 in Cleveland, OH. This special issue of *Cities and the Environment* features a series of papers arising from that conference.

A guiding theme of the conference and papers in this issue is a focus on smaller-scale (meters to 10^2 meters) parcels of land (or patches) defined by, e.g., legal property boundaries that are directly or indirectly managed by the properties’ owners (as for residential households, apartment complexes and commercial properties) or other institutions (as for government agencies managing public lands). This focus complements other efforts to examine larger-scale ($\geq 10^3$ m) dynamics and planning of urbanized regions (Forman 2008; Grimm et al. 2008). However, larger-scale urban patterns and dynamics ultimately emerge from the combination of smaller-scale parcel management decisions and effects (Odum 1982; Pouyat et al. 2006; Grimm et al. 2008). Thus, understanding the emergent properties of larger urban regions (*sensu* Kaye et al. 2004)—the scale at which many environmental planning and management policies are targeted—depends on examination of patterns and relationships among social and ecological variables at the scale of landscape parcels (e.g., a yard around a single-family home). Although an exclusive focus on individual parcels may not alone contribute to a full understanding of urbanized ecosystems, it provides an essential complement to a larger-scale perspective.

Additionally, individual landscape parcels represent the scale at which people readily think about the urban environment and, therefore, where landscaping choices, activities, and environmental consequences are most apparent, comprehensible, intimate, and immediately made. Thus, parcels provide a personal human-scale focus useful for engaging parcel owners and managers in thinking—in a “down-to-earth” way—about how their individual landscaping choices affect environmental variables, both positively and negatively. Such engagement can be made more meaningful by discussing information from a growing, but incomplete, body of research which reveals some of the important sociocultural variables that interactively affect human landscape design and management choices and activities within a parcel, including income, aesthetic preferences, advertising, public policies, and peer pressure (Jenkins 1994; Hope et al. 2003; Byrne 2005; Larsen and Harlan 2006; Clayton, 2007; Robbins 2007; Baker et al. 2007). Helping people understand the underlying reasons for their landscaping choices and the effects of

those choices on environmental variables should be essential foci for educational outreach programs that seek to positively transform the social norms, behaviors, and public policies associated with urban landscape design and management. A major challenge for increasing the overall sustainability and environmental quality of urbanized societies and ecosystems is developing effective educational messages about the methods of ecological landscaping and the importance of adopting them.

The discussion above provides the thematic context for the papers in this special issue (also see Byrne 2008 in this issue for further introduction). In the remainder of this introductory paper, we define our use of the phrase ecological landscaping and develop a conceptual framework to illustrate the interdisciplinary complexity associated with the causes and consequences of urban landscape management practices. This framework is then used as a lens through which to summarize important points from each of this issue's articles. We conclude by suggesting key questions, challenges, and future directions for ecological landscaping research and practice. Our hope is that ideas raised in this special issue will contribute to increased interest in and research about this increasingly important topic.

WHAT IS ECOLOGICAL LANDSCAPING?

Because it may have various meanings to different people, it is necessary to clarify our use of the phrase "ecological landscaping." First, "landscaping" refers to either 1) the set of design and maintenance activities associated with landscape manipulation or 2) the collection of biotic and abiotic physical structures within a given area produced and maintained by those activities. In colloquial use, as in landscaping companies or landscaping a yard, the word connotes both the practices and products of common lawn and garden management such as choosing and installing ornamental vegetation, mowing lawns, weeding, and watering. We adopt the word to bring forth these two meanings which help focus attention on the on-the-ground, parcel scale of urbanized landscapes; indeed, many of the characteristics of a landscape parcel are ultimately determined by the landscaping activities carried out within it.

In addition, because "landscaping" suggests many practices rather than focusing on one activity over others, its use provides an opening for simultaneously examining diverse aspects of the urban landscaping endeavor. As such, it serves as an inclusive, neutral, umbrella word that can foster interdisciplinary discussion about the scholarly study and everyday practices of landscape management. For instance, within a discussion about landscaping, information and perspectives from ecology, horticulture, and the social sciences, among other fields, should be included and synthesized. However, ideas from landscape managers must also be considered because, as the ones actively shaping the physical structure of urbanized environments, they may have different insights and concerns than scholars. We propose that the word landscaping has well-established, colloquial appeal and can thus help bring landscape managers (including industry professionals and private homeowners) and their ideas into discussions that might otherwise become overly academic and removed from everyday situations. In this way, landscaping is an integrative word that links scholarly theories with on-the-ground application, an essential outcome for effecting positive changes to landscaping norms and practices.

In many ways, all landscaping has an ecological dimension because both landscaping practices and products affect, and are affected by, environmental variables within a parcel. (For example, irrigation practices affect plant growth and are affected by local precipitation and a soil's water holding capacity.) However, this does not presuppose that all landscaping is properly called ecological in a strict sense because many activities are carried out without regard for their broader environmental effects. In most cases, urban landscaping activities are guided by a focus on maintaining the health and appearance of ornamental plants and desired state of other landscaping elements (e.g., walls, paths). Certainly, this focus is relevant and makes sense as it is the *raison d'être* for many urban landscaping practices. However, with this ecologically-limited perspective, landscape managers may view landscaping elements in isolation from their environment and inadvertently exclude, or deliberately ignore, other relevant factors

that can—and arguably should—guide socially and environmentally responsible landscaping decisions. As such, the ubiquitous plant/structure-centered landscaping perspective and the landscaping designs and activities associated with it should not be called “ecological” because their purview is too focused on certain variables while possibly excluding others completely.

Instead, use of the word ecological to describe landscaping should be reserved for specific instances when landscaping practices and products are influenced by a broader, more holistic perspective. The essence of this perspective, as informed by an understanding of contemporary ecological science (Odum and Barrett 2005; Cary Institute of Ecosystem Studies 2008), is a synthetic approach for examining the interconnected relationships among organisms, abiotic conditions and resources, and environmental patterns and processes (especially the transformations and flow of matter and energy) both within and outside of an individual landscape parcel. This ecological science view is related to what Fritjof Capra (1996, 2002) has called “systems thinking” because, with it, our focus shifts from individual parts (i.e., a reductionist view) to the patterns and dynamics of relationships among all parts comprising a system (Cary Institute of Ecosystem Studies 2008). In addition, a more holistic, ecosystems view emphasizes that all individual landscape parcels lie within the environmental context of larger landscapes that affect the embedded parcels. Likewise, what occurs in parcels can affect the larger ecosystems and landscapes of which they are a part, possibly leading to feedback loops and indirect effects across spatial scales and among seemingly unrelated variables (Grimm et al. 2008; Cadenasso and Pickett 2008). This ecological, systems worldview is reflected in the colloquialism that nothing can be understood in isolation because everything is connected to everything else. Indeed, sayings such as this might provide effective, colloquial talking-points for educational outreach programs that seek to engage the public in thinking about the ecology and sociology of urban landscaping. Capra (1996, 2002) provides additional discussion and details about systems thinking and ecological literacy.

Compared to the plant/structure-focused landscaping perspective, a more ecological, systems-oriented viewpoint shifts attention from individual, managed organisms (plants, pests) and structures to interactions among all parts (variables) of the landscape, including unmanaged ones, with each other and those of surrounding ecosystems. Two important points follow from this perspective. First, variables not usually considered within the urban landscaping endeavor are recognized as integral parts of a larger system that may have relationships to focal managed elements within a parcel. For example, birds and spiders are not direct targets of many landscaping activities but are important consumers of pests; thus, an ecological landscaping approach considers how landscaping practices (e.g., plant selection, pesticide applications, mulching) and products (e.g., density and composition of trees and shrubs) might positively or negatively affect the abundance and predation rates of these natural enemies (Rebek et al. 2005; Byrne 2007). In addition, with an ecosystem perspective, potential consequences of landscaping activities for variables outside the managed parcel must be considered to avoid what Odum (1982) called “the tyranny of small decisions:” the aggregation of individual choices that cause large-scale environmental problems. These two points have important implications for decisions about how to design and manage landscapes more efficiently and sustainably. For instance, realization that chemical applications could have negative effects on beneficial organisms, nearby waterways, and human health might effect a reduction or elimination of their use (Potter et al. 1990; Nishioka et al, 1999; Bormann et al. 2001; Robbins 2007).

Another dimension of contemporary ecological science that bears on the ecological landscaping perspective is the objective of integrating humans and sociocultural variables into the study of environmental patterns and processes (Redman et al. 2004), a goal exemplified by the field of urban ecology (Pickett et al. 1997, 2008; Grimm et al. 2008). Results of urban ecology studies indicate complex and sometimes surprising relationships between sociocultural and environmental variables within urbanized ecosystems (Pickett et al. 2008). For example, household income, advertising, environmental ethics, and aesthetic values, among other factors, have been found to influence urban ecological patterns,

especially of plant communities, more than traditional physical-ecological variables because these sociocultural variables drive human landscaping choices and activities that dictate vegetation patterns (Hope et al. 2003; Larsen and Harlon 2006; Clayton 2007; Robbins 2007). In addition, surveys have found that although over half of U.S. households use landscaping chemicals (Law et al. 2004; National Gardening Association 2004), many people do not readily connect their personal landscaping activities to broader environmental concerns such as water pollution and the potential for indoor pollution (Nishioka et al. 1999; Robbins 2007). Such information is needed to understand how and why people design and manage urbanized environments. This understanding also provides a foundation for developing education programs that seek to help people appreciate relationships between parcels and “big-picture” environmental issues and, in turn, make more informed landscaping choices (Baker et al. 2008). To encourage such reflection, landscape parcels could be referred to as “social-ecological systems” (*sensu* Redman et al. 2004) and the phrase “social-ecological landscaping” could be used in certain contexts. For simplicity however, we suggest that “ecological landscaping” can, by definition, include examination of sociocultural variables as drivers of urban landscape practices and products.

We readily acknowledge that the phrase *ecological landscaping* has been used by others and that the concepts it embodies draw from a rich history of scholarly work (especially within the field of landscape architecture, a review of which is outside the scope of this paper). Certainly, the goals of the Cleveland Ecological Landscaping conference and this special issue were to build on and advance the efforts of others. For example, the Ecological Landscaping Association, based in Framingham, Massachusetts, was formed in 1992 to promote “change in landscaping practices through educating landscape professionals and the public” (Ecological Landscaping Association 2008). Some landscape architects and landscaping companies have also adopted the phrase to describe their work (e.g., Terra Nova 2004; Four Dimensions 2008). In addition, the word *ecological* has been used to create other phrases that have meaning similar to ecological landscaping but with slightly different emphasis on spatial scale or management foci, including ecological horticulture (Stewart 2008) and ecological planning (Thompson and Steiner 1997). Other organizations (Wild Ones 2008; National Wildlife Federation 2008), projects (Sustainable Sites Initiative 2008), and scholars (Smith et al. 2007) are also actively advancing the ideas and practices of sustainable urban landscaping. Regardless of the phrase used, a commonality among these efforts is the explicit embracement of a “green” or “environmentally friendly” ethic to guide urban landscaping for improving environmental quality. In our use of the phrase *ecological landscaping*, we also hope to bring forth a set of ecocentric values.

A SOCIAL-ECOLOGICAL FRAMEWORK FOR ECOLOGICAL LANDSCAPING

Conceptual frameworks are important tools that help organize ideas into systematic relationships and provide insights into new research topics and questions (Pickett et al. 2007). They have been particularly useful in the field of urban ecology for describing interdisciplinary relationships among sociocultural and ecological variables (Pickett et al. 1997; 2008, Pouyat et al. 2006; Grimm et al. 2008). Drawing from other ecosystem and urban ecology frameworks and content of papers in this issue, we constructed a conceptual framework to help organize and advance the study of ecological landscaping (Fig. 1). Although the content and organization of this framework shares some broad similarities with others, it is differentiated by its focus on individual landscape parcels (Fig. 1A). This focus provides an appropriate starting point from which to develop an interdisciplinary ecological landscaping framework because parcels are the discrete units about which landscape managers make landscaping decisions and within which they carry out landscaping activities, a point echoed by Cadenasso and Pickett 2008. Therefore, each individual parcel is a unique social-ecological system that, for research purposes, is amenable to fine-scale examination of relationships among sociocultural and ecological variables. In addition, parcels provide tangible, personal foci for ecological landscaping education programs.

Table 1. Fundamental questions that can guide research about the practice of ecological landscaping.

- How should sustainable urbanized landscapes function and what should they look like?
- What is the quantity and quality of previous research that is available to provide a foundation for understanding the ecological and social characteristics of urbanized environments?
- What are the key research gaps and needs that need to be resolved to make future progress in developing sound scientific principles and sustainable practices for ecological landscaping?
- What are the positive and negative environmental, health, social and economic effects of common urban landscape management practices?
- How can we most efficiently create and maintain urbanized landscapes that are environmentally, economically and socially sustainable over long timescales?
- What sociocultural, economic, policy and political factors influence the ways in which people design and manage urbanized landscapes?
- How can we bring about positive changes in public attitudes for adopting more sustainable urban landscaping norms and practices?
- How can changes to public policies be effected to guide people toward more sustainable urban landscape design and management?
- Can educational programs about scientific principles change people's perspectives about appropriate and sustainable urban landscaping practices?

To reflect the holistic, systems-thinking perspective needed for a rigorous approach to ecological landscaping, the framework is developed in two ways. First, a traditional input-output ecosystem model (*sensu* Likens 1992 and Odum; Barrett 2005) is employed to emphasize how an individual landscape parcel is connected to its broader environmental context through the flow of materials and energy across its boundaries. Second, the framework explicitly incorporates many sociocultural and physical-ecological components which are not usually considered within a plant/structure-centered view (in addition to those that are) and shows how they are interrelated as inputs, internal parcel characteristics, and outputs. Although not illustrated in the figure, many direct and indirect relationships exist among the sociocultural and ecological variables, giving rise to a synthetic, complex social-ecological framework for examining the causes, dynamics, and consequences of ecological landscaping practices and products.

A landscape parcel can be described by a set of physical-ecological (including landscaping products) and management characteristics. The physical ecological characteristics (Fig. 1B) are the biotic and abiotic structures including vegetation, walls, and sidewalks; the abiotic conditions; spatial patterns of these three variables; and ecological processes associated with population dynamics, food webs, and transformations of energy, matter, and nutrients within the parcel (Cary Institute of Ecosystem Studies 2008). These variables relate directly and indirectly to human management decisions and practices which help characterize the sociocultural characteristics of a parcel (Fig. 1C). Management decisions lead to management activities that directly affect many of a parcel's physical-ecological characteristics,

especially the composition and spatial patterns of structures. Management practices may also indirectly affect unmanaged variables through changes in managed variables (e.g., mulch applications impact earthworm populations that change soil properties; Byrne et al. 2008). In some instances, changes in physical-ecological variables not directly caused by human activities can spur management decisions and practices as when pest outbreaks catalyze pesticide applications. Many common landscape management practices, like mowing, weeding, and mulching, are used specifically in response to undesired structural changes of plants or other materials. The dynamic feedback relationship between changes in physical-ecological characteristics and management decisions and practices is probably a universal characteristic of urban landscape parcels (Cadenasso and Pickett 2008). Although the nature of these dynamics may be intuitive, this explicit description of landscape parcels as social-ecological systems (Fig. 1A, B, C) is an essential foundation for a rigorous ecological landscaping framework.

Management decisions about a parcel are not made solely on the basis of characteristics within the parcel; rather, a wide range of external variables, both physical-ecological and sociocultural, also influence landscaping decisions. Within a traditional ecosystem model, these can be conceptualized as inputs to the landscape parcel (Fig 1D). Many physical-ecological inputs enter without human regulation including animals, plant seeds, precipitation, sunlight, and gases. The effects of these environmentally-derived inputs (Fig. 1E) on a landscape parcel depend on many factors including the amount and timing of the input and a parcel's internal characteristics. For example, both beneficial (e.g., predatory) and harmful, pest organisms enter parcels in varying numbers over the seasons; whether they establish populations will depend on the availability of favorable habitat and human management responses. Although the entry of environmentally-derived physical-ecological inputs into a parcel is, for the most part, uncontrollable, these variables should be considered when management decisions are made because some of the parcel's characteristics can be manipulated to affect how these inputs influence the parcel's other characteristics and the outputs leaving it (e.g., precipitation inputs leave as runoff; Baker et al. 2008, Shuster et al. 2008).

Other physical-ecological inputs to a landscape parcel are directly controlled by humans (Fig. 1F). These include, among other things, purchased plants and their packaging; the irrigation water, pesticides, fertilizers, and tools used for managing the health and growth of plants; mulches; materials for creating and managing abiotic structures; and the electricity and fossil fuels needed to operate tools. Unlike environmentally-derived inputs, the timing, amount, and frequency of human-controlled inputs depend on a manager's landscaping decisions. These are influenced by a combination of many factors including the processing rates of inputs in the parcel (e.g., water and fertilizer uptake by plants), their durability and disposability (e.g., lifespan of tools and plants), and, for many inputs, a diversity of sociocultural variables.

Sociocultural variables (Fig. 1G) that affect landscaping decisions and practices (Fig. 1C) can also be envisioned as inputs to a landscape parcel. They affect the physical-ecological characteristics of a parcel (Fig. 1A) by influencing the human-controlled physical-ecological inputs (Fig. 1F) and what happens to them in the parcel (Fig. 1C). In addition, sociocultural variables also affect choices about how to manage some environmentally-derived inputs such as pests (Fig. 1E). The personal aesthetic, environmental, and social-responsibility values of a landscape manager play a central role in decisions about landscaping (Larsen and Harlan 2006; Clayton 2007; Hitchmough 2008) as does the manager's financial abilities to purchase desired inputs (i.e., a luxury effect; Hope et al. 2003). In addition, a certain amount of "peer pressure" is exerted on landscape managers via neighborhood covenants (Martin et al. 2003), local "weed laws" (Rappaport 1993; Sandberg and Foster 2005), historical cultural legacies, and advertising by the landscaping industry (Jenkins 1994; Larsen and Harlan 2006; Robbins 2007). These external social factors interact to generate social norms (or standards) about "proper" landscaping practices and products that responsible citizens are expected to follow (Byrne 2005; see below). However, scientific information about effective landscaping methods (e.g., leaving lawn clippings in place as a

nutrient source; Kopp and Guilliard 2002) are also externally-derived inputs transmitted via various educational routes that can also impact landscaping decisions and characteristics of a parcel. Thus, for a holistic approach to ecological landscaping, understanding is needed about how sociocultural variables act as inputs that affect a manager's monetary and informational resource bases and his/her personal values regarding landscaping which in turn affect a parcel's physical-ecological characteristics through management activities.

Increased understanding of relationships among the sociocultural and physical-ecological variables in individual parcels is critically important for future study because these relationships ultimately determine the emergent sustainability of larger urbanized regions (Odum 1982; Grimm et al. 2008). In particular, the spatial and temporal dynamics of urbanized regions are affected by the physical-ecological and sociocultural outputs leaving individual parcels (Fig. 1H). Physical-ecological outputs (Fig. 1I) consist of biotic and abiotic solids, liquids, and gases as well as thermal energy generated by energy transformations in the parcel or reradiated from solar inputs. The thermal characteristics of a parcel (as affected by its physical-ecological properties) partially affect its microclimate conditions and may contribute to the urban heat-island effect (Byrne et al. 2008). Inorganic solid outputs include unwanted and/or unusable wastes such as packaging from plants and landscaping materials, broken or unwanted tools, and other garbage. Biotic wastes include plant materials that leave a parcel as garbage or materials for local composting programs.

While solid outputs are usually managed directly by humans, other outputs are indirectly affected via management activities' effects on a parcel's physical-ecological characteristics. These outputs include dispersing organisms (e.g., weed seeds); gases produced by organisms and fossil fuel combustion; and water leaving a parcel through evaporation, percolation to ground-water, and run-off, the latter two of which may contain other chemicals (e.g., pesticides, fertilizers). The amount and composition of outputs are determined directly or indirectly by those of the inputs as well as how the inputs are managed, transformed, and retained within a parcel (Baker et al. 2008). In many cases, outputs (like blowing seeds or leaves) are likely to become inputs to another parcel. A common output that readily crosses parcel boundaries is the noise generated by landscaping tools such as lawn mowers and leaf blowers; while certainly noticeable by humans, the collective noise created in urbanized environments has also been found to affect the songs of urban birds (Slabbekoorn and Margriet 2003; Wood and Yezerinac 2006). Although other research has been conducted on the physical-ecological outputs from urbanized landscapes (e.g., gases: Kaye et al. 2004; Byrne et al. 2008; water and nutrients: Easton and Petrovic 2004; Frank et al. 2006), this aspect of the ecological landscaping framework remains a relatively unexplored area of study in need of future study.

Also contributing to the total physical-ecological outputs associated with a landscape parcel are the solid waste, greenhouse gases, and waste water generated during the manufacturing and transport of materials used as landscaping inputs (Fig. 1E, J). Even though these indirect outputs occur offsite and out of a landscape manager's sight, they are important to consider because they may be large and have significant local and broad-scale environmental effects (e.g., as contributions to climate change). Few studies have quantified the indirect outputs associated with landscaping materials (Parker 1982). However, given that the U.S. landscaping industry generates an estimated \$147.8 billion in annual economic activity (Hall et al. 2006), it is reasonable to assume that the total amount of these byproducts will also be large. Further investigation of this topic presents a challenging objective for future research.

In addition to physical-ecological outputs, a landscape parcel also produces sociocultural outputs (Fig. 1K). A central concern for most landscape managers is how the appearance of physical-ecological elements in a parcel communicates information to others (i.e., visual aesthetic outputs). As proposed by Nassauer (1988), "cues to care"—including pruned shrubs, weeded flower beds, mowed lawns and well-maintained structures such as fences and paths—are socioculturally important because they help show

that a land owner and/or manager is adhering to widely held social norms or legal requirements about acceptable landscaping (Piekielek 2003; Robbins 2007). Therefore, landscaping products are also “costly signals” because they require resource inputs to maintain the physical-ecological communication signals that symbolize that the parcel’s owner and/or manager is respectable and responsible member of the community (Piekielek 2003; Larsen and Harlan 2006). In turn, a kind of sociocultural feedback among landscape parcels can be generated when conformity to landscaping norms within one parcel (an output) serves a sociocultural peer pressure input to other parcels (Fig. 1L; Byrne 2005). Indeed, studies have found that adjacent parcels are more likely to have similar landscaping than those farther apart due to this “keeping up with the Jones’s” effect (Zmyslony and Gagnon 1998). Pickett et al. (2008) suggest that this pattern (especially regarding lawn management) helps build social capital within communities that contributes to the overall sustainability of urbanized ecosystems. In addition, urban landscaping practices and products have been documented to have beneficial effects on people’s physiological, psychological, and social well-being (Kaplan et al. 1998). Increasing such sociocultural ecosystem service outputs should be an important goal of ecological landscaping.

Although some beneficial ecosystem services may arise from urban landscaping, certain lawn and garden design and management approaches have been increasingly questioned in recent years because of their negative effects on human health, biodiversity and the overall environmental quality and sustainability of urbanized ecosystems (Stein 1993; Bormann et al. 2001; Waskowski and Waskowski 2002; Robbins 2007; Tallamy 2007). These negative effects, which may be called “ecosystem disservices” (Byrne et al. 2008), include generation of air, water, and soil pollution, inefficient use of energy, and negative effects on biodiversity and food webs that increase the possibility of pest outbreaks (Zenger and Gibb 2001; Baker et al. 2008). Some ecosystem disservices generated in urbanized regions may result from the collective outputs from many landscape parcels and thus appear outside of and distant from each parcel that contributes to them. In turn, information about these negative effects can be used as educational inputs of information to landscape parcels that might catalyze landscaping changes (Fig. 1L) as well as lead to public policy changes such as bans on pesticide use (Sandberg and Foster 2005). Emphasis of systematic feedback relationships among landscaping inputs, parcel characteristics and outputs within the framework presented here (Fig. 1) highlights its utility as a tool for analyzing and promoting more integrated, socio-ecological and systems-thinking approaches to designing and managing urbanized landscapes.

PAPERS IN THIS ISSUE

The study of ecological landscaping falls under the broader heading of urban ecology. Thus, it is not surprising that the structure and content of the ecological landscaping framework (Fig. 1) reflects many themes in the paper by Cadenasso and Pickett (2008), who propose five scientific principles to form a general theory of urban ecology. Collectively, four of these principles describe urbanized areas as dynamic, spatially and temporally heterogeneous, integrated ecosystems whose emergent characteristics arise from interactions among social (including information) and biophysical variables. Although urbanized ecosystems are often viewed as human-dominated, Cadenasso and Pickett (2008) emphasize in their fifth principle that basic physical-ecological processes are still important for determining many of their basic properties, as is also emphasized in our framework (Fig 1B, E, J). In addition, they provide a thoughtful summative, discussion about a central aspect of the ecological landscaping conference’s theme (Fig. 1): how scientific principles can be translated into ecological landscape design and management practices that help increase the sustainability of urbanized ecosystems.

In his paper, Martin (2008) also utilizes scientific information to develop a set of landscape design and management guidelines. His focus is on the urbanized arid region around Phoenix, Arizona and, thus, the dynamics of water usage within landscape parcels. In the context of ecosystem services and resilience, he reviews ecological landscaping research to show how socio-ecological variables such as

economic status and preferences influence landscape managers' decisions and activities, specifically for plant selection and management. In terms of the ecological landscaping framework (Fig. 2), Martin (2008) highlights the need for large irrigation water inputs to sustain the desired physical-ecological characteristics of lawns and other "oasis" vegetation within this desert biome. Although such water use may seem wasteful, he points out that greener landscape parcels provide cooler microclimates by mitigating the effects of solar radiation inputs. In conclusion, he proposes that, within each landscape parcel, a balance should be sought among practices that minimize water inputs and those that increase the value of ecosystem service outputs (including aesthetic value). Resolving trade-offs is a challenge that requires integration of scientific and design principles. In addition, elucidating general guidelines that are applicable to all, or many, individual parcels of a region may be a central problem for the study and practice of ecological landscaping (Byrne et al. 2008).

While Martin's (2008) focus is mainly vegetation, Marzluff and Rodewald (2008) draw attention to how human manipulation of plant communities and landscape patterns impact animal, especially bird, populations. Drawing from general ecological theories and numerous studies, they discuss scientifically-informed guidelines for designing and managing urbanized regions and individual parcels in ways that support a higher diversity of animal species (e.g., by providing favorable nesting and food resources). In particular, two of their points exemplify an ecological approach to landscaping. First, they note that human provision of bird feeders can significantly affect the abundance and distribution of various bird species across urbanized areas. By affecting the inputs of an important environmentally-derived input (birds) to a parcel, this activity may affect other physical-ecological characteristics of a parcel in ways that affect landscaping practices (e.g., birds feed on pests that reduce the need for pesticides; Fig. 1E; Tallamy 2007). Second, they emphasize the need for a large-scale approach to thinking about relationships between landscape and biodiversity patterns because the ability of one landscape parcel to support wildlife is affected by—and in turn will affect—the ability of surrounding parcels to do so since many animals move readily among human-defined parcels. These points emphasize two central aspects of the ecological landscaping framework: the importance of considering variables not traditionally defined as landscaping practices (feeding birds), and the value in examining relationships between individual parcels and the environment surrounding them. As Marzluff and Rodewald (2008) suggest, such insights can help guide management and restoration activities in urbanized areas that lead to more successful biodiversity conservation.

Three papers in this issue discuss the management of a parcel's inputs and outputs of water. The focus of Baker et al. (2008) is the nutrient load carried with runoff from lawns that can contribute to the pollution of water bodies. They hypothesize that, in a given urbanized area, a large proportion of polluting nutrients (nitrogen and phosphorous) are likely derived from a small subset of all the parcels (i.e., a "tyranny of small decisions" effect; Odum 1982). Baker et al. (2008) develop a disproportionality framework that can be used to indicate which parcels have the physical-ecological (e.g., soil), sociocultural (e.g., managers' attitudes), and management (e.g., fertilizer application) characteristics that would, alone or in combination, generate a higher likelihood of producing excessive, polluting runoff. They argue that such a framework can lead to the development of more personalized educational outreach messages targeting the owners and managers of higher-polluting lawns. As an example of the type of cross-disciplinary integration needed in ecological landscaping studies, they discuss how social science theories (especially those of reasoned action and planned behavior) can inform the content and approaches of more effective educational programs that help decrease water pollution by effecting changes in parcel managers' knowledge, attitudes, and landscaping decisions and behaviors.

Another conclusion suggested by the Baker et al. (2008) paper is the importance of analyzing the site-specific characteristics of a landscape parcel to guide effective management of its water outputs. This point is also emphasized by Shuster et al. (2008) in their discussion of methods for altering the internal characteristics of landscape parcels to reduce runoff. Using two case studies, they describe approaches for

engaging stakeholders (homeowners, local governments) in the processes of adopting landscaping practices that help process and/or retain storm water at its source (e.g., removing impervious surface, installing rain gardens and barrels), thus preventing it from entering sewers and nearby bodies of water. Their approach exemplifies a large-scale social-ecological systems perspective for landscaping because they emphasize the value of 1) including many stakeholders in the landscaping decision-making, design and management processes and 2) considering urbanized regions as integrated systems whose emergent hydrological patterns are affected by the collective processing and outputs of water in individual landscape parcels. In addition, Shuster et al. (2008) emphasize the important role of public policies and incentives to encourage and facilitate landscaping that generates ecosystem services regarding the desirable flow of water through urbanized ecosystems.

In an additional analysis of urban hydrological dynamics, Carter and Butler (2008) draw our attention up from the ground-level with their studies about the physical-ecological characteristics of green roofs. In the context of ecological landscaping, green roofs may help increase the overall sustainability of urban landscape parcels by replacing the ecosystem disservice of increased runoff from impervious roofs with the service of increased storm water retention. Data provided by Carter and Butler (2008) support this conclusion with storm water retention rates in vegetated roof parcels of ~30 to 85%, depending on the total precipitation volume per storm. In addition, they present data about the ability of green roofs to increase the energy efficiency of buildings and the effects of weather conditions on growth rates of different plant species on roofs. Such data contribute to the development of scientific principles to guide green roof landscaping practices and the policies that support their creation.

The theme of using scientific principles to guide ecological landscaping also appears in Hitchmough's (2008) thought-provoking essay. Specifically, he draws from 15 years of his own research about the ecology of designed plant communities to develop a new philosophical view about the ecological and sociological meanings and functions of urban green spaces. In part, this integrated view emphasizes the importance of allowing for a landscape parcel's specific physical-ecological contextual and internal conditions to dictate how it is designed and managed. This contrasts with situations in which sociocultural factors lead to landscaping practices that try to "force" plants to survive in locations where they otherwise would not (e.g., turfgrasses in the desert; Larsen and Harlan 2006, Martin 2008). As he discusses, an implication of this view is that the use of non-native species and novel combinations of plants may be needed to create long-lasting, low maintenance landscapes in locations where the physical-ecological conditions do not allow native plants and communities to persist (a conclusion relevant to green roofs as supported by data in Carter and Butler 2008). In addition, he proposes that the sustainability of plant communities which are products of landscaping depend on how local human inhabitants respond to the sociocultural informational outputs (e.g., seasonal color, cues to care) that emerge from them. In this way, Hitchmough's essay suggests an important sociocultural metric for assessing the overall sustainability of landscaping products: those that are appreciated by the public are sustainable; those which are disliked are not. However, a challenge for widespread adoption of ecological landscaping may be reconciling the, perhaps conflicting, sociocultural and physical-ecological aspects of what determines acceptable sustainable urban landscaping (as when intensive lawn management is socioculturally desired but generates negative outputs; Martin 2008, Baker et al. 2008).

When conflicts arise between the sociocultural and physical-ecological desires for landscaping, engaging community members in the discussion, analysis, and design of alternative ecological landscaping strategies may be essential for reaching solutions (as is exemplified by the case studies described by Shuster et al. 2008 and implied in the discussions of Baker et al. 2008 and Marzluff and Rodewald 2008; see also McKenzie-Mohr and Smith 1999). One model for community engagement is a citizen science program in which non-scientists participate in a study that has real-world relevance (Bäckstrand 2003). In their paper, Taylor et al. (2008) describe an innovative high-school education program in which students are being trained as citizen scientists who collect data about the physical-

ecological characteristics of their local urbanized ecosystems. Although still in its initial stages, Taylor et al. (2008) report encouraging evidence of positive outcomes from this program including increased student interest in learning and conducting science. Thus, this program—and especially its exemplary use of educational theory and technology to guide the curriculum—can inform the development of others that seek to engage students of all ages in learning and collecting data about the unique social-ecological characteristics of their neighborhood environments. Such public engagement may go a long way toward increasing citizens' interest in understanding—and concern for—how the landscaping practices they engage in affect the ecosystems in which they reside while remedying the effects of “nature-deficit disorder” on urban residents, especially children (Louv 2008).

CONCLUSIONS, CHALLENGES AND FUTURE DIRECTIONS

For the first time in history, more humans now live in urbanized than rural environments; the growth trends of urbanized areas and populations are expected to continue into the foreseeable future (Pouyat et al. 2006; United Nations 2007; Grimm et al. 2008). Thus, the overall well-being of most people is, and will increasingly be, intimately linked to the environmental quality of urbanized environments. Thus, a major challenge to ensuring the long-term sustainability of human societies is creating and maintaining urbanized ecosystems in which the ecosystem services and biodiversity that support human well-being are conserved and, where needed, restored (Millennium Ecosystem Assessment 2005). In addition, sustainable environments are those that humans wish to maintain because they find them aesthetically pleasing, an important sociocultural dimension of sustainability (Kaplan et al. 1998; Hitchmough 2008). To help guide the creation of sustainable urbanized societies and ecosystems, this paper has presented a description of, and conceptual framework for, ecological landscaping that connote a holistic, integrated sociocultural-ecological and systems-thinking perspective and approach for designing and managing urbanized landscapes. However, real-world creation of ecological landscapes may be challenged by a lack of four supporting factors: 1) sufficient scientific information about the causes, characteristics, and consequences of different landscaping practices and products, 2) ecological landscaping guidelines, 3) widespread public understanding of ecological science and systems thinking, and 4) sociocultural norms and public policies that embrace ecological landscaping practices. For ecological landscaping to become widely valued and adopted, further progress must be made in all these areas simultaneously. In this section, we conclude by briefly discussing these four challenges with an eye toward possible future directions in the study, practice, and public education about ecological landscaping.

Certainly, scientific research and principles should play a central role in shaping ecological landscaping practices and products (Byrne 2008). Although much research has been conducted in many fields that has relevance to this topic, a coherent body of ecological landscaping research has not yet emerged. Possible questions to guide such research (Table 1) cross many traditional disciplinary boundaries, including the natural and social sciences, education, and design and planning fields. Thus, development of an integrated scholarly study of ecological landscaping depends on dissolution of these boundaries to facilitate collaborative, inter- and transdisciplinary research. In this effort, a challenge will be discussing and reconciling differences in paradigms and vocabularies underlying the disciplines. This became clear during the review and editing of papers for this special issue because authors, reviewers, and editors occasionally had conflicting views about the meaning of words and concepts used in different ways across different fields. The ecological landscaping framework (Fig. 1) could help resolve disciplinary communication problems and provide a guide for future interdisciplinary, collaborative work to address important ecological landscaping questions (Table 1).

Another challenge for progress in ecological landscaping is elucidation of general guidelines for the practices involved in designing and managing sustainable urbanized landscapes. In this issue, Martin (2008) and Marzluff and Rodewald (2008) suggest possible guidelines for ecological desert landscaping and successful conservation of urban vertebrate wildlife, respectively. Although they drew from extensive scientific research, their guidelines might be limited by the specific organismal, geographic, and

sociocultural contexts in which the reviewed research was conducted; thus, it is uncertain how applicable these guidelines are to other organisms and geographical areas. Examining how the causes, consequences and interpretation of certain landscaping practices and products vary in different contexts represents an exciting challenge for future work that calls for large-scale, cross-biome collaborations (Byrne et al. 2008).

Others have also made progress toward listing guidelines for ecological landscaping (a review of which is outside the scope of this paper but see: Kaplan et al. 1998; Smith et al. 2007; Ecological Landscaping Association 2008; Sustainable Sites Initiative 2008). In the spirit of contributing to this discussion, we suggest here a short list of general, summative guidelines for sustainable, ecological landscaping within an individual landscape parcel by drawing from the framework presented above (Fig. 1). At this point, these guidelines are by necessity very general, preliminary and in need of supporting research to provide more specific insights about how the guidelines should be implemented in different contexts. Nonetheless, their presentation here may help guide future research. These ecological landscaping guidelines are:

1. Examine relationships among as many physical-ecological variables in and outside the parcel as possible (especially those not traditionally considered part of the landscaping endeavor) to uncover potentially unexpected indirect relationships and unintended effects;
2. Minimize material and energy inputs (collectively resource use) and direct and indirect negative outputs (generation of solid waste and pollution) associated with an individual parcel;
3. Use energy and materials within a parcel as responsibly and efficiently as possible, in particular by reusing and recycling as much as possible;
4. Drawing from the best available scientific data and principles, design and manage landscapes in ways that maximize the conservation of ecosystem services (including sociocultural ones) and associated beneficial biodiversity while minimizing ecosystem disservices (Millennium Ecosystem Assessment 2005; Tallamy 2007; Byrne et al. 2008);
5. Reflect on the sociocultural factors that influence landscaping decisions and question their importance and relevance in context of the guidelines listed above and the societal objective of creating sustainable, healthy urbanized ecosystems.

In addition to being very general, these guidelines require a certain level of familiarity with ecological science and systems thinking to comprehend their broader context, meaning, and relevance. Thus, two additional challenging tasks emerge for taking scientific principles and ecological landscaping guidelines into the “real world” of urbanized environments. First, scholars familiar with the ideas underlying the essential framework and guidelines of ecological landscaping should increase efforts toward translating them into less-technical language and materials for other audiences, especially professional landscape managers and public policy makers. (Although the content of this paper could be used for this purpose, such translation was outside its scope.) In concert with these efforts, new environmental education programs need to be developed to increase societal understanding about why anyone should care about ecological landscaping in the first place. Ecological landscaping educational programs will overlap with broader science and environmental literacy programs already established, including citizen scientist efforts (Capra 1996, 2002; Bäckstrand 2003; Taylor et al. 2008). For school children especially, the value of using urbanized landscapes for environmental education programs is obvious given their accessibility and relevance to people’s daily lives (Louv 2008; National Wildlife Federation 2008).

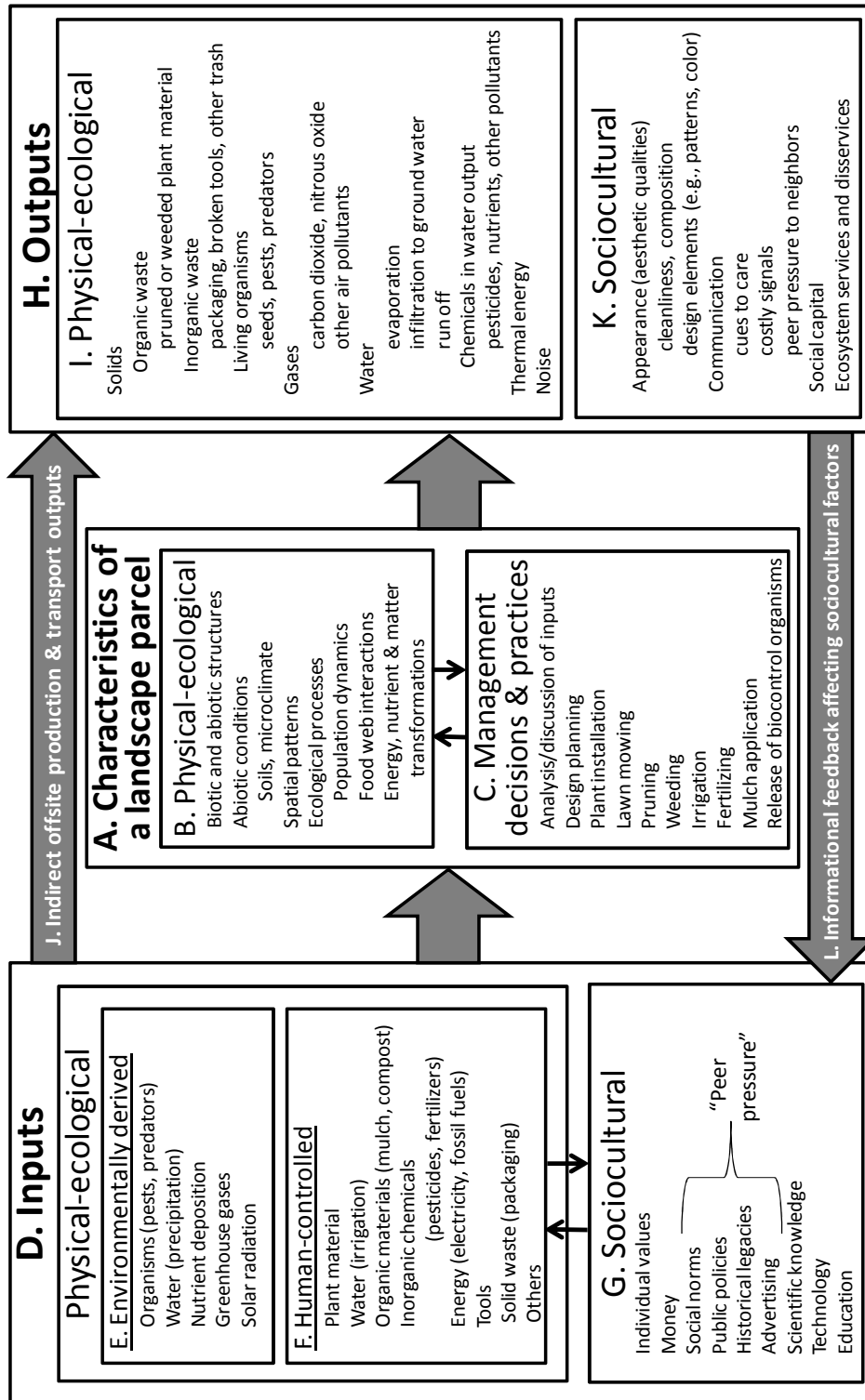


Figure 1. This synthetic, holistic conceptual framework illustrates the interconnected relationships among sociocultural and physical-ecological variables that affect the characteristics of an individual landscape parcel. A traditional inputs-outputs ecosystem model (Likens 1992, Odum and Barrett 2005) provides the central organization of the framework. Detailed description of the framework’s components is provided in the text.

It is reasonable to assume that widespread, sustained outreach efforts about the practices and value of ecological landscaping are essential to bring about large-scale changes in social landscaping norms, given the enormous inertia and feedback loops in place that maintain the predominant aesthetics-driven, plant/structure-centered view (Jenkins 1994; Byrne 2005; Robbins 2007). In turn, effective outreach programs—perhaps taking the form of public service and social marketing campaigns—could “nudge” (*sensu* Thaler and Sunstein 2008) people toward sustainable changes in attitudes, decisions and behaviors related to landscaping (McKenzie-Mohr and Smith 1999; Baker et al. 2008). This may be very difficult in some instances because some common landscaping norms are in direct opposition to what ecological landscaping guidelines suggest are more sustainable practices (e.g., the desire for high-input “perfect” lawns versus more ecologically sustainable low-input or “freedom” lawns; Bormann et al. 2001). As highlighted by some of the papers in this issue, reconciling opposing socioculturally- and ecologically-derived expectations for sustainable landscapes may be the greatest challenge that needs to be overcome for achieving more widespread adoption of ecological landscaping practices and products (Hitchmough 2008; Martin 2008). However, increased study of these challenges, along with development of strategies for and case studies documenting successful changes, provide insights into future directions for initiating positive changes in urban landscape design and management practices and public policies (Rappaport 1993; McKenzie-Mohr and Smith 1999; Martin et al. 2003; Sandberg and Foster 2005; Shuster et al. 2008). We suggest that greater appreciation for scientific principles in general and specifically for those related to ecological landscaping will underlie increased success for such efforts. Our hope is that this paper and others in this special issue help catalyze greater visibility, understanding, research, and adoption of ecological landscaping perspectives, practices, and policies that lead to more sustainable urbanized societies and ecosystems.

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