WORLD RESOURCES INSTITUTE

ISSUE BRIEF

CREATING VALUE THROUGH ECOSYSTEM SERVICE MANAGEMENT IN URBAN AND SUBURBAN LANDSCAPES

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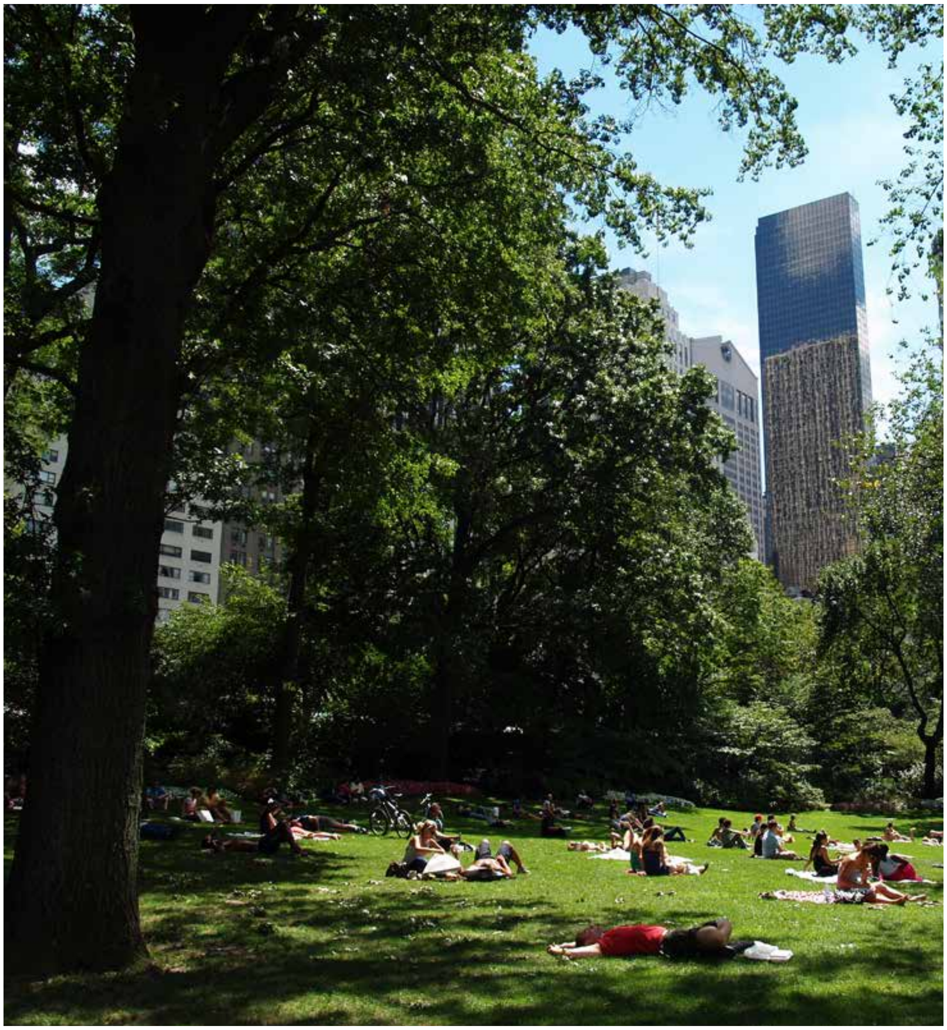
SUMMARY

In this Issue Brief, we examine (1) how integrating ecosystem services into landscape management can increase the economic, environmental, and social values generated by managed landscapes for both private landowners and surrounding communities, and (2) how these considerations can be operationalized into landscape decision making, by utilizing tools and methods available today.



Managed landscapes, such as residential lawns, golf courses, and parks, are deeply interconnected to a range of urban and suburban environmental, social, and economic issues. These links partly stem from landscapes' provision of ecosystem services including stormwater retention, climate moderation, and improved air quality, which in turn affect populous communities' health and well-being. These landscapes are often privately owned and intensively managed; in fact, landscape management is a $40 billion industry in the United States (Ghali et al. 2010). However, conventional landscaping business practices and sustainability initiatives rarely consider the full range of ecosystem services potentially derived from managed landscapes. As a result, much of the environmental, social, and economic value of these landscapes remains untapped and unmanaged.

New tools and methods for measuring and economically valuing ecosystem services are emerging. These methods can be applied to managed landscapes to guide a range of design and management decisions, including which vegetative covers and management practices to use to produce different environmental outcomes. Ecosystem service assessment and valuation are already being applied in agriculture and forestry sectors.

Creating Value through Ecosystem Service Management in Urban and Suburban Landscapes, a joint effort by the World Resources Institute and Cardno ENTRIX, describes the ecosystem services approach and how it relates to managed landscapes. It reviews the economic, environmental, and social benefits derived from managed landscapes with a focus on seven ecosystem services: aesthetic and recreation opportunities, water quality, air quality, carbon sequestration, local climate control, water retention, and soil retention. These services can be quantified and economically valued using existing methods.

Finally, the brief proposes a conceptual ecosystem service framework for managed landscapes, to aid in operationalizing and eventually standardizing these considerations into landscape management. A recommended next step is for relevant stakeholders to test this framework on managed landscapes, working toward an elaborated standard framework to evaluate managed landscapes and the ecosystem services they provide. Toward this goal, this Issue Brief is accompanied by a more detailed white paper, *A Framework to Quantify and Value Turfgrass Ecosystem Services* (MacNair et al. 2013).

INTRODUCTION

Unlocking the potential of managed landscapes

Managed landscapes, including residential lawns, golf courses, and parks are deeply interconnected to a range of urban environmental and economic issues like urban water quality, heat islands, air quality, and health (see Box 1 for definitions of managed landscapes and other key terms). These links partly stem from landscapes' provision of ecosystem services including stormwater retention, climate moderation, and improved air quality, which have a positive impact on public well-being. For example, well-managed urban and suburban landscapes can sequester one ton of carbon dioxide per acre annually, and can absorb and store more rainwater than a wheat field (Qian and Follet 2002; UMD 1996). These landscapes also enhance people's physical and social well-being by providing space to socialize and enjoy being outdoors. Ultimately, millions of people benefit from these landscapes and the ecosystem services they provide.

As urban areas grow, there is ever more value in maximizing ecosystem services within managed landscapes to enhance environmental health and community livability. Landscape sustainability initiatives provide an ideal platform for scaling up ecosystem service management. However, these initiatives tend to focus on reducing environmental costs associated with resource inputs through prescribed practices or technology options (USGBC 2012b; SSI 2013; WaterSense 2012). While resource use efficiency is an essential component of sustainable landscape management, a focus on minimizing environmental costs may overlook opportunities to maximize the positive value of ecosystem services, and could even risk undermining the provision of such benefits.

We propose that integrating ecosystem service considerations into landscaping decisions will create value for both private owners and society. Taking this approach could bolster landscape sustainability initiatives by enabling adoption of:

- **RESULTS-ORIENTED INDICATORS** Shifting indicators from set practices and technologies toward results-oriented measures of performance can provide a consistent, objective way of tracking progress toward set social, environmental, and/or economic goals. Estimating or directly measuring environmental performance can inspire innovation and produce on-the-ground results, above and beyond practice-based benchmarks currently used in many landscaping sustainability initiatives (Greenhalgh, Selman, and Guiling 2006). Quantifying ecosystem services is one way to measure sustainability performance and instill results-oriented indicators in managed landscapes.
- **NET BENEFITS ASSESSMENTS** Building on current sustainability frameworks that focus on reducing environmental costs (e.g. water use, carbon emissions), to include the range of environmental, social, and economic values resulting from landscape management (e.g. water balance, carbon balance), can yield science-based measures of net benefits, and help identify opportunities to become "net positive." Net benefits can be calculated by measuring positive and negative environmental, social, and economic impacts in terms of their costs and benefits.
- **VALUE CREATION FOR LANDOWNERS, AS WELL AS SOCIETY** Properly managed landscapes can provide a range of benefits to the site-specific interests of private landowners and to the broader public. The emerging field of ecosystem service valuation enables the use of monetary values as a basis for comparison across various environmental and social parameters important to multiple stakeholders (WBCSD 2011). Decision makers can use these values to optimize ecosystem services to meet the needs of private landowners and the public.

Managed landscapes, including residential lawns, golf courses, and parks are deeply interconnected to a range of urban environmental and economic issues.

Aligning public and private interests to utilize managed landscapes for their ecosystem services is not a new concept, but it's also not common practice. Because ecosystem service metrics and valuation are not commonly monitored and reported, there is a lack of real-world information on the actual and potential economic, environmental, and social values provided by managed landscapes. However, with emerging information and more robust methods of measuring ecosystem services, there is now potential to incorporate scientifically defensible, quantitative measures of ecosystem services into sustainability guidelines and site-specific management to drive value creation.

Shifting the discourse to an emphasis on positive ecosystem service outcomes from well-managed landscapes is a marked departure from the current focus on minimizing environmental costs. Combining the resources, expertise, and efforts of nongovernment organizations, industry, and policy makers to test and adopt ecosystem services measures for landscaping could yield even more substantial economic, social, and environmental benefits than currently achieved.

BOX 1

KEY TERMS

In this Issue Brief, the term "**managed landscape**" refers to landscaped areas such as parks, residential lawns, sports fields, and other privately managed parcels of open space in urban and suburban settings.

Ecosystem services are the aspects of nature from which people derive benefit. For example, wetlands purify water, mangroves protect shorelines and coastal settlements, and forests and other vegetative covers prevent soil erosion.

Quantification of ecosystem services refers to estimating a numeric measure of an ecosystem service's quantity or quality.

Valuation of ecosystem services refers to estimating a monetary value of an ecosystem service. Not all ecosystem services that are measured and quantified need to be valued, only those that provide services directly to people (Boyd and Banzhaf 2006). This Issue Brief considers two types of valuation: the market value of ecosystem services (including the contribution of ecosystem services to property values), and avoided cost of replacing a service if the ecosystem service was degraded or lost. There are other methods of valuating ecosystem services, but they are not addressed in this document (e.g. EPA 2009; WBCSD 2011).

Landscape management practices are actions taken to create and maintain a managed landscape. Examples include irrigation, pest management, harvesting, species introduction, and land use change. Landscape management practices affect the biodiversity and health of the ecosystem, which in turn can affect delivery of ecosystem services. Landscape design and construction are also interlinked with ecosystem services.

Landscape sustainability initiatives are efforts involving nongovernment organizations, government agencies, and industry groups to promote sustainable landscape management. They often provide guidance, education, benchmarks, and certification for landscapes (see SSI 2013; USGBC 2012b; Watersense 2012 for examples).

An ecosystem service **net benefit** is calculated using the value provided by an ecosystem service and subtracting the reduction of those benefits related to practices or inputs. For example, the net carbon benefit flowing from a landscape would be calculated using the economic value of carbon sequestration and storage taking place on a landscape and subtracting the value of carbon emissions associated with constructing and managing that same landscape (through, for example, lawn mowing, fertilization practices, and energy use for irrigation).

ABOUT THIS ISSUE BRIEF

This Issue Brief proposes that integrating ecosystem service considerations into landscaping decisions will increase the economic, environmental, and social values of managed landscapes for both private owners and the public. It has four sections:

- **SECTION I. ABOUT MANAGED LANDSCAPES** introduces urban and suburban managed landscapes, and the decision makers who influence landscape management.
- **SECTION II. HOW AND WHY TO ASSESS ECOSYSTEM SERVICES** describes the ecosystem services approach and how it relates to managed landscapes. We review examples of how the agriculture and forestry sectors have already created value by incorporating ecosystem services into management decisions.
- **SECTION III. A REVIEW OF ECOSYSTEM SERVICES DERIVED FROM MANAGED LANDSCAPES** summarizes the economic, environmental, and social values derived from properly managed landscapes, as presented in peer-reviewed literature. We found that aesthetic and recreation opportunities, water quality, air quality, carbon sequestration, local climate control, water retention, and soil retention are among the ecosystem services most highly related to managed landscapes. These services can be quantified and economically valued in a managed landscape context using existing methods.
- **SECTION IV. RECOMMENDATIONS ON AN ECOSYSTEM SERVICE FRAMEWORK FOR MANAGED LANDSCAPES** proposes a conceptual framework for operationalizing and perhaps eventually standardizing an ecosystem service approach for managed landscapes.

The study described here was a joint effort by the World Resources Institute and Cardno ENTRIX, with input from scientific and industry specialists at John Deere and Syngenta. It is accompanied by a more detailed white paper, *A Framework to Quantify and Value Turfgrass Ecosystem Services* (MacNair et al. 2013).

I. ABOUT MANAGED LANDSCAPES

What are managed landscapes?

Managed landscapes are ecosystems that are planned, created, and managed for specific economic or social outcomes. Though the term can refer to forests and agricultural lands, or to broader units such as a watershed, in this Issue Brief the term "managed landscape" refers to landscaped areas such as parks, residential lawns, and sports fields and other privately managed parcels of open space in urban and suburban settings. These landscapes are often privately owned and managed by specialists; landscape management is a $40 billion industry in the United States (Ghali et al. 2010).

Managed landscapes play a more important role in the environmental and social well-being of communities than one might think:

- Eighty-two percent of the United States population currently lives in urban areas, where managed landscapes are most prominent (CIA 2012; EPA 2010a). Most Americans come into contact with this type of landscape every day.
- Among the varied features of these landscapes, turfgrass is a hallmark. The 40 million acres of managed turfgrass in the United States is enough to cover the entire state of Kentucky; by acreage, turfgrass is the third largest cultivated crop in the country—covering more land than rice, cotton, or wheat. It is the largest irrigated crop in the United States (EPA 2012a; Milesi et al. 2005).
- Trees are another major feature of managed landscapes. The U.S. Forest Service estimates tree canopy covers as much as 35 percent of urban areas, approximately 20.9 million acres (USFS 2010).

Although rarely acknowledged for their social, environmental, and economic importance, these managed landscapes are ubiquitous and therefore play a prominent role in the urban land cover mosaic.

Who manages urban and suburban landscapes?

A variety of actors influence the management of urban and suburban landscapes—from homeowners to park managers, and often times industry specialists. The following groups are involved throughout the life cycle of a managed landscape:

- **LANDSCAPE ARCHITECTS AND DESIGNERS,** who significantly influence the provision of ecosystem services. For example, landscapes can include design features intended to provide ecosystem services, such as stormwater containment areas or shade trees (EPA 2012c). In general, a landscape's design determines the management practices needed to maintain that landscape, which further influences the provision of ecosystem services.

- **LANDSCAPE MANAGERS**—including homeowners, athletic field directors, lawn care operators, grass seed and crop protection suppliers—who control the day-to-day management of ecosystem services affected by managed landscapes. Some landscape managers are professionally trained, others are not.
- **GROUPS INVOLVED IN LANDSCAPE SUSTAINABILITY INITIATIVES** that work toward the development of sustainability criteria for landscapes and can influence their management. Some sustainable landscape initiatives are educational, while others provide certification options. Trade associations, nonprofit organizations, and corporations have engaged in developing landscape assessment methods and metrics that could include ecosystem service values as part of their efforts (EIFG 2012; Field to Market 2012; SSI 2012; USGBC 2012a).
- **LOCAL GOVERNMENTS AND ENVIRONMENTAL REGULATING BODIES** that may determine the conditions for landscape design, construction, and management, and create policy incentives for environmental stewardship. Landscape management responds to regulations and sustainability frameworks promoted by policy makers and industry, so recognizing ecosystem services in policy is a key component of catalyzing sustainable landscape management (EPA 2012b).

The decision context influencing managed landscapes is complex; a private manager's decisions can affect ecosystem services, and at times can intersect with public goals. For instance, managed landscapes can play an influential role in helping or hindering municipalities' regional water quality goals—by either providing tertiary water treatment, or causing stormwater runoff, depending on landscape design and management (CSN 2009). Also, landscape design and construction phases significantly influence the management practices required for a landscape, and each phase of the landscape lifecycle engages a different set of actors. Therefore, multi-stakeholder collaboration is a necessity for sustainable management of these landscapes.

II. HOW AND WHY TO ASSESS ECOSYSTEM SERVICES

This section describes the fundamental components of an ecosystem service approach and how they relate to urban and suburban managed landscapes. Similar industries, like

the agriculture and forestry sectors, have already successfully incorporated ecosystem services into management decisions, and have created value by doing so.

Multi-stakeholder collaboration is a necessity for sustainable management of these landscapes.

Identifying ecosystem services of strategic importance

Site-specific assessment is important to understanding the quantity and value of ecosystem services relevant to a particular landscape. Regional and site-specific variations affect which ecosystem services are present within a landscape and which are important to local communities. For instance, urban green space in dry, hot areas could provide shade and evapotranspiration that help to moderate local temperatures. Or, a forested hill slope might prevent landslides by holding soil in place, providing the ecosystem service of erosion control. Provision of these ecosystem services could increase or decrease based on how the landscapes are managed.

A number of tools and assessment methods exist to help identify the most important ecosystem services in a particular landscape. These tools and methods apply to a wide range of sectors and decision making contexts. For the corporate sector, a popular ecosystem service assessment tool is the *Corporate Ecosystem Services Review*, which helps business managers identify ecosystem services of high importance to their operations (Hanson et al. 2012). There are numerous assessment methods and case studies available to inform public sector decision making as well (BSR 2013). Most of these methods are broad and can be tailored to fit different purposes and geographic contexts.

Quantifying ecosystem services

Quantifying ecosystem services can be useful for monitoring, benchmarking, and reporting sustainability performance. These services should be quantified using scientifically accepted metrics that reflect economic, social, and environmental outcomes. This brief focuses on the measurement and metrics of ecosystem service flows—the rates at which ecosystem services are delivered to beneficiaries (Layke 2009). The tons of carbon sequestered or gallons of water absorbed over a period of time are examples of metrics that quantify such flows.

Many ecosystem services such as erosion control, water quality, and carbon sequestration are routinely and consistently estimated as environmental outcomes (Greenhalgh, Selman, and Guiling 2006). Others, such as a landscape's ability to improve air quality, are not commonly quantified. When it is difficult to directly measure an ecosystem service, it may be necessary to rely on proxy indicators. Proxy indicators are substitute metrics used to provide insight into an issue of interest when it cannot be directly measured (Layke 2009). For example, measurement of airborne particles known as particulate matter (PM) is often used as a proxy for overall air pollution (Smith and Huang 1995).

Some ecosystem services can be directly measured through empirical means, while other services can be credibly (and cost-effectively) estimated through modeling. For example, the ecosystem service of water retention can be modeled by the *Water Quality Analysis Simulation Program (WASP)*, a general framework for modeling contaminant transport in surface waters (EPA 2010b).

Some forest and agriculture sustainability initiatives have incorporated ecosystem services into educational tools and certification programs. For example, the Forest Stewardship Council's Ecosystem Services Program aims "to increase the applicability and relevance of FSC certification for forest management activities focusing on the provision of ecosystem services" by incorporating ecosystem service indicators into certification schemes (FSC 2013). Likewise, Field to Market's Fieldprint Calculator calculates the net benefits

Factoring in broader environmental and social costs and benefits could create shared value for business and communities.

of farm operations across an array of environmental and social criteria (Field to Market 2013). These and similar tools can be used to benchmark a managed landscape's sustainability performance, as well as to compare a landscape's performance to local or national averages.

Valuing ecosystem services

Valuation of ecosystem services refers to estimating the monetary value of the benefits of an ecosystem service. This can inform private sector decisions by communicating the importance of ecosystem services, comparing the costs and benefits of investing in these services, and identifying possible market values or revenue streams from an ecosystem service (WBCSD 2011). Ecosystem service valuation can also be used to estimate monetary figures that help with comparing landscape performance across various environmental and social parameters.

Identifying the appropriate ecosystem services for valuation is a significant challenge. Many ecosystem services are important, but do not provide direct value to society and therefore should not be valued directly. For example, nutrient cycling and runoff control are ecosystem services that affect water quality. Society does not directly benefit from nutrient cycling or runoff control, but indirectly benefits from their contribution to water quality through such effects as reduced drinking water treatment costs and improved water quality aesthetics. By valuing water quality changes, we also include the value (as it relates to water quality) of nutrient cycling and runoff control.

There are a variety of methods for economically valuing ecosystem services, and different methods measure different types of value (EPA 2009; WBCSD 2011). Property value is an example of a market value that is impacted by the presence or absence of valuable ecosystem services. For example, property values have been found to correlate with air quality, so properties in close proximity to ecosystems that purify air may have a higher property value (Nowak et al. 2006; Smith and Huang 1995). On-site trails and greenbelts have also been shown to increase property value by 2 and 5 percent respectively, as has proximity to golf courses and other open-space amenities (Asabere and Huffman 2009).

Another useful method of ecosystem valuation is the estimation of cost savings due to ecosystem services (WBCSD 2011). For example, wetlands can reduce flooding and consequent damage to homes—and it is possible to estimate these avoided costs. Likewise, one can also estimate the "replacement cost" of building or utilizing a man-made substitute for an ecosystem service, if the service becomes degraded or disappears. For example, it is possible to measure the expected increase in air conditioning costs resulting from loss of an ecosystem's ability to naturally moderate the local climate.

The agriculture and forestry sectors have already created value from ecosystem services, beyond the marketable products of food and timber. For example, New York City pays upstream landowners for improved forest and farmland management as a nature-based means of filtering pollutants and sediment out of drinking water reservoirs (Talberth and Hanson 2012). Other cities have also discovered that it is often cheaper to maintain healthy forests than to build conventional water filtration facilities to meet their water quality goals. This cost-saving for the city also represents a revenue stream for private landowners who manage the ecosystem service of water filtration on their lands.

Within cities, landscapes can also be managed for ecosystem services that benefit communities and create an economic return, although there are fewer examples here than in other sectors. The Center for Neighborhood Technology's (CNT) Green Values Calculator integrates a few ecosystem services into landscape design and management. Designed for planners, engineers, and individual property owners, the Calculator quantifies costs and benefits associated with installing green infrastructure for improved stormwater management. The net benefits of green infrastructure can then be compared with those of traditional stormwater infrastructure (CNT 2013). In many cases, using green space for stormwater treatment can represent a cost saving over traditional stormwater investments (SSI 2009).

Applying ecosystem services assessment to managed landscapes

While the landscaping industry, like most industries, conventionally tracks its success on a narrow range of economic indicators, factoring in broader environmental and social costs and benefits could create shared value for business and communities (Porter and Kramer 2011). A better understanding of the values that can be derived from well-managed landscapes will allow property owners to realize the full range of benefits their landscapes offer. There are several ways in which ecosystem service assessment could uncover value for private landowners or managers, while also creating value for society and the environment. These include:

- **OPPORTUNITIES TO REDUCE OPERATIONAL OR COMPLIANCE COSTS.** For example, managing landscapes for local climate moderation can reduce air conditioning costs, and ecosystems can purify water that would otherwise be routed through a treatment facility. Urban shade trees have also been shown to generate as much as $200 per tree in air conditioning savings and avoided healthcare costs from smog (Akbari 2002).
- **NEW REVENUE STREAMS FOR LANDOWNERS** through emerging financial incentive programs (including carbon trading and credits), ecosystem markets, and award/certification programs. For example, some cities are providing financial incentives for homeowners to enhance the ecosystem services of water retention on their lands to complement public stormwater management actions (CNT 2010; NRDC 2011).
- **IMPROVING MARKETABILITY AND GENERATING COMMUNITY GOOD WILL** by establishing baselines and reporting on credible sustainability measures related to environmental outputs and ecosystem services. Methods highlighted in this review identify potentially affected ecosystem services that are important to communities and include metrics for quantifying these ecosystem service flows. These metrics can be used in sustainability reporting and in communications with customers and communities.
- **ENABLING LOCAL AND REGIONAL GOVERNMENTS TO INCENTIVIZE ECOSYSTEM SERVICE MANAGEMENT.** As government strives to develop policies that encourage ecosystem service stewardship, it will benefit from an improved understanding of the economic values of ecosystem services enjoyed by the broader public. Ecosystem service valuation can inform policies and incentives that reward private landscape management decisions that generate ecosystem service benefits for surrounding communities.

The field of ecosystem services assessment is nascent, but rapidly evolving. Though there are many success stories where an ecosystem service approach has improved decision making, the field is not yet developed or widely applied as standard practice (Hanson et al. 2012; NCP 2010). In addition, despite the wide variety of approaches and distinct architectural structures that have emerged to fit specific decision contexts, no standardized framework for incorporating ecosystem services

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Managed landscapes contribute to community livability by reducing noise pollution, improving community cohesion, and promoting physical health.

into the managed landscapes decision context currently exists (BSR 2013; Grigg 2009; IFC 2011). Thus, there is not complete information on the net values of the many ecosystem services affected by managed landscapes.

To start developing a standardized ecosystem services framework for managed landscapes, a review of academic research on the topic sheds light on the scale and economic importance of ecosystem services in urban and suburban settings. In the next section, we review the economic values potentially derived from managed landscapes, highlighting applicable metrics and valuation techniques.

III. A REVIEW OF ECOSYSTEM SERVICES DERIVED FROM MANAGED LANDSCAPES

This section discusses evidence that properly managed landscapes can generate ecosystem services on-site, and deliver benefits to surrounding communities beyond the fence line. These findings are based on a review of the best available studies on the magnitude and economic value of seven ecosystem services provided by properly managed landscapes.

This Issue Brief identified seven priority ecosystem services relevant to urban and suburban settings. They were selected because of their potential value to society; the availability of data to quantify and value the services; and their ability to cover a range of important benefits, without significant double counting of those benefits. The services are: aesthetic and recreation opportunities, water quality, air quality, carbon sequestration, local climate control, water retention, and soil retention. All are affected by landscaping and can be managed to deliver environmental, social, and economic value. The services reviewed in this section are classified in accordance with published literature on the topic (Costanza 2008; Hanson et al. 2012; MEA 2005; TEEB 2010).

A sample of quantification and valuation methods for each ecosystem service is outlined below. Each service is currently quantifiable using existing metrics and supporting data. Credible valuation methods also currently exist for each service, though there is a lack of peer-reviewed studies focused on valuation in urban settings. The economic values of ecosystem services referenced below are therefore included purely for illustration.

A. Aesthetic and recreation opportunities

About this service. Managed landscapes provide ecosystem services that generate recreational and aesthetic benefits to people. For example, homeowners, customers, and the public can receive these benefits from well-managed landscapes through their enjoyment of a game of golf or the homes they live in. Managed landscapes contribute to community livability in many other ways, from reducing noise pollution, improving community cohesion, and promoting physical health (CNT 2011). Documented mental health benefits from exposure to managed landscapes include stress reduction, restoration from mental fatigue, and improved cognitive functioning. For example, participation in activities in green spaces has been shown to alleviate symptoms of Alzheimer’s, dementia, and depression (Bell et al. 2008).

Quantifying this service. The level of recreational and aesthetic services affected by managed landscape features varies based on the size of the area (square feet) as well as its visual appearance, which can be measured on factors such as color, density, texture, production of seed heads, etc. The appearance and health of turfgrass can be assessed using a system developed by the National Turfgrass Evaluation Program (NTEP). Quality ratings include consideration of nine aesthetic and functional factors and NTEP provides a rating system of 1 (poorest or dead grass) to 9 (outstanding or ideal turf) (NTEP 2012). Digital imagery can be used to standardize turf quality ratings and remove some of the subjectivity from the analysis (Ghali et al. 2010).

Valuing this service. The recreational and aesthetic values of managed landscapes can be partially measured by their impact on property value. But property values are only part of the value to landowners who have to invest in lawn maintenance on an annual basis. Homeowners derive value in excess of these annual expenditures, which is not captured by property values. Nevertheless, studies show that homeowners significantly value both landscaping within their property boundaries and proximity to green space. Public green space and private landscaping can increase home valuations by 2–12 percent (Acharya and Bennett 2001; Asabere and Huffman 2009; Henry 1999; Stigarll and Elam 2009). Although these studies provide general estimates about managed landscapes, none provide a direct link between this service and the quantification metrics identified above.

B. Water quality

About this service Managed landscapes can significantly affect the water quality of surrounding areas through the flux of pollutants such as nitrogen, phosphorus, and sediment, which often enter streams and rivers during storm events in urban areas (EPA 2012c). When managed to do so, these landscapes can reduce water runoff, and soil erosion, which also contributes to water pollution. However, improper application of fertilizer or pest treatments in managed landscapes may increase the level of pollutants in water runoff.

Quantifying this service. A landscape's ability to purify water can be quantified as the net amount of nutrient pollution reduced by the landscape before entering water bodies. It can be measured in pounds of nutrients added or removed per acre, per year. A landscape's runoff reduction and absorption rates can be measured empirically through monitoring runoff or instream water quality, or through models such as:

- *Water Quality Analysis Simulation Program (WASP)*, a general framework for modeling contaminant fate and transport in surface waters (EPA 2010b).
- *Exposure Analysis Modeling System (EXAMS)* for modeling aquatic ecosystems, rapidly evaluates the fate, transport, and exposure concentrations of water pollution (EPA 2005).

- *Causal Analysis/Diagnosis Decision Information System (CADDIS),* provides background on many common sources, stressors, and biotic responses in stream ecosystems (EPA 2010c).
- *Load Estimator (LOADEST)* estimates constituent loads in streams and rivers (USGS 2009).
- *Turf PQ* models chemical infiltration and runoff from turfgrass (Haith 2001).

Valuing this service. This ecosystem service can be valued using the cost of reducing nutrient concentrations through engineered methods as a surrogate. For landscapes that filter nutrients out of water runoff, the avoided costs of phosphorus removal may vary from $4 to $505 per pound, depending on the entity bearing the cost and the method used to estimate it (Hubbard, Biedenham, and Ashby 2003; Keplinger et al. 2004).

C. Air quality

About this service. Managed landscapes, like all ecosystems, influence air quality by emitting chemicals to the atmosphere, and by filtering and extracting chemicals from the atmosphere. Landscaped areas can improve air quality by removing air pollutants. Specifically, vegetation absorbs and intercepts such potentially harmful pollutants as nitrogen dioxide, particulate matter, ozone, and sulfur dioxide (Nowak et al. 2006). Certain landscape management practices can emit chemicals to the atmosphere, for example, during mowing and fertilizer use.

Quantifying this service. Airborne particles known as particulate matter (PM) are often used as a proxy for overall air pollution levels as it is a major contributor to haze (which reduces visibility) and is also a threat to respiratory health (Smith and Huang 1995). Another reason PM is a good proxy indicator is that sulfur dioxide and nitrogen dioxide both contribute to PM counts. A landscape's contribution to air quality can be measured in tons of PM removed or emitted per year (Smith and Huang 1995). A 1994 study by the U.S. Forest Service found that trees in New York City removed an estimated 1,821 metric tons of PM through interception of airborne particles and uptake of gaseous pollutants (Nowak 2002).

Valuing this service. The valuation of air quality improvements from managed landscapes can be based on the effect on property values. According to a meta-analysis of 86 peer-reviewed studies, the average value of reducing one ton of PM is approximately $237 per house in the affected area (Smith and Huang 1995). However, the value per ton of improved air quality varies significantly based on the existing level of air pollution, as changes in concentration at certain pollution levels are less detectable.

Valuation of air quality improvements from managed landscapes is based on impacts to property values, but there may be health benefits as well. Unfortunately, there is limited transferability of values from studies on the health benefits of air quality improvements.

D. Carbon sequestration

About this service. Vegetation can absorb and store greenhouse gases (especially carbon dioxide) from the atmosphere. Turfgrass, for example, removes carbon dioxide from the atmosphere and stores it either within its structure or in the soil. Urban trees also reduce the amount of atmospheric carbon by sequestering it in new tissue growth (USFS 2007). Some landscape management practices like mowing release carbon dioxide into the atmosphere.

Quantifying this service. Carbon sequestration from managed landscapes can be measured as tons of carbon dioxide added or removed from the atmosphere. Turfgrass has a high rate of greenhouse gas sequestration, especially when the landscape is managed to minimize soil disturbances (Pouyat, Nowak, and Yesilonis 2006). Under some

> Landscaped areas absorb and intercept potentially harmful pollutants such as nitrogen dioxide, particulate matter, ozone, and sulfur dioxide.

management practices, turfgrass can sequester carbon at rates similar to or greater than those in grassland and forest systems (Pouyat, Yesilonis, and Golubiewski 2008). Qian and Follett (2002) found that turfgrass could store up to one metric ton of carbon per acre per year for 25 to 30 years after establishment. Other land use activities like afforestation and rangeland management have the potential to sequester between 1 to 10 metric tons of carbon per acre annually (Johnson, Gorte, and Ramseur 2010). A 2007 study by the U.S. Forest Service found that the urban forest in Minneapolis, MN stores an estimated 250,000 tons of carbon each year. Several tools exist to measure this ecosystem service, such as Daycent, which models the amount of carbon stored in soils through historic and modern levels of soil organic carbon (Kenna 2011; Parton et al.1998).

Valuing this service. The price of carbon in voluntary markets ranges from $9 to $26 per metric ton depending on the projects associated with the offset (e.g. geothermal energy, wind energy, or reforestation) (Green Mountain Energy 2012; Native Energy 2012.) The appropriate value per ton of carbon sequestered from turfgrass management is expected to be on the lower end of offset costs, perhaps $10 per metric ton (Kenna 2011).

E. Local climate control

About this service. Ecosystems influence local temperature, precipitation, and other climatic factors by reducing surface temperatures in urban areas, and therefore also reducing energy consumption associated with air conditioning (Akbari 2002). Managed landscapes in urban and suburban areas can help relieve the "urban heat island effect" where roads, parking lots, and developments absorb and hold in solar energy, increasing local surface temperatures (Beard and Green 1994).

> Managed landscapes in urban and suburban areas can help relieve the "urban heat island effect".

Quantifying this service. The cooling effects of managed landscapes are the result of evapotranspiration, which can be measured to approximate local climate ecosystem services (Beard and Green 1994; UMD 1996). Estimates of net evapotranspiration are based on average annual growing season. In addition to evapotranspiration, trees also reduce temperatures through the shade they provide. These combined effects can be estimated in terms of average temperature degrees increased or decreased per year. One study of the Phoenix, Arizona area characterized the urban heat island effect according to different population density (Brazel et al. 2007). The study found that the core urban area of Phoenix was approximately 1 to 2 percent warmer than areas associated with medium density residential development where residential lawns and other managed landscapes are more prevalent.

Valuing this service. Several studies have been conducted to estimate the economic value of heat island mitigation from trees, but very few studies estimate the value of heat island mitigation from turfgrass and other essential features of managed landscapes. One study found that shade trees on the south side of buildings can save up to $47 per tree per year in energy costs (Peper, McPherson, and Simpson 2007). Other studies found that tree canopy reduces residential home cooling costs by 7-40 percent (EPA 2012c).

F. Water retention

About this service. Managed landscapes have the potential to increase groundwater infiltration, mitigate stormwater runoff, and reduce flooding. Design factors such as soil type, slope, and vegetation mix significantly influence the quantity or quality of this ecosystem service. Conversely, over-irrigation may increase the level of water runoff.

Quantifying this service. Turfgrass and forested areas' water retention can be measured by the gallons of water runoff associated with the landscape. One study found that turfgrass offers a six-fold greater efficiency in absorbing rainfall compared to wheat fields and a four-fold greater efficiency than a typical hay field (UMD 1996). An inventory of green spaces with mixed tree and grass cover in Beijing found that 2,494 cubic meters of potential runoff were stored per hectare of green area. The total volume of rainwater stored in these green spaces nearly equaled the volume demanded by the area's water users (Zhang et al. 2012).

Another study of green space in Santa Monica, CA found that trees intercepted approximately 1.6 percent of total precipitation annually, providing savings in stormwater treatment and flood control costs (Seitz and Escobedo 2012). Managed landscapes' potential for stormwater infiltration and floodwater mitigation is so great that the Federal Emergency Management Agency (FEMA) provides reduced flood insurance rates to communities that implement green infrastructure for water retention in excess of federal standards (FEMA 2013).

Several tools exist to measure this ecosystem service, including:

- *Soil & Water Assessment Tool (SWAT)*, a river basin scale model developed to quantify the impact of land management practices in large, complex watersheds (Arnold 1990).
- *The Agricultural Policy Environmental EXtender (APEX)*, a tool for managing small watersheds to obtain sustainable production efficiency and maintain environmental quality (BREC 2012).

Valuing this service. The value of landscape water retention can be measured as the avoided cost to treat a gallon of water at an urban stormwater management facility. An EPA review of 17 municipalities concluded that use of on-lot bioretention areas cost 15–40 percent less compared to conventional stormwater management (EPA 2007). Landscape water retention can also be measured in terms of avoided infrastructure costs. Seattle Public Utilities found that installing green infrastructure (such as bioswales and permeable surfaces) in lieu of traditional "gray" infrastructure (such as curbs and gutters) for water retention generated cost savings of $100,000 to $235,000 per block, and is likely to provide cost savings over the lifetime of the project (CNT 2010). These cost savings are only realized if these entities are actually required to implement additional nutrient removal measures in the absence of the landscape. In Philadelphia, for example, the municipal water department charges nonresidential landowners a stormwater utility fee based in part on the impervious surface area of their land. Landowners can avoid this fee by utilizing green infrastructure and offsetting impervious surfaces on their property (NRDC 2011).

G. Soil retention

About this service. Vegetative cover can reduce soil erosion by catching and anchoring soil particles in place and also by reducing soil water content, which can affect slope stability (Beard and Kenna 2006). Managing for soil retention can provide private on-site value by avoiding costs of building retaining walls and other erosion mitigation practices. Moreover, the landscape's ability to retain soil impacts the quality of the landscape.

Quantifying this service. The impact of landscaping on soil retention can be measured by metric tons of soil conserved or lost per year from a given area. Soil loss equations and available simulation models like the USDA's Soil and Water Assessment Tool (SWAT) can be used to quantify this ecosystem service (Arnold 1990).

Valuing this service. The value of erosion control in landscaping can be most easily measured based on the cost of replacing topsoil. Property values can also be affected by erosion, but this correlation varies significantly by location.

This section provides the evidence base which confirms what many nongovernment organizations, industry groups, and policy makers have long speculated, but have yet to operationalize—that properly managed landscapes can provide valuable solutions to urban and suburban environmental, social, and economic challenges. By leveraging ecosystem service metrics, valuation techniques, tools, and models available today, it is possible to measure the various ecosystem services affected by managed landscapes in terms of economic costs and benefits to landowners and to society.

Table 1 summarizes these seven ecosystem services, presents methods to quantify and value benefits relevant to managed landscapes, and indicates whether a given service primarily benefits private landowners or the broader public. It should be noted that these seven ecosystem services could benefit the broader public, depending on the location and specifics of the site.

TABLE 1

VALUABLE ECOSYSTEM SERVICES PROVIDED BY MANAGED LANDSCAPES IN URBAN AND SUBURBAN AREAS

Service	Metric	Possible valuation measure	Value to landowner	Value to broader public
Aesthetic and recreation opportunities	Landscape quality rating by square footage	Added property value, measured in percentage increase of property value per additional square footage of turfgrass	x	
Water quality	Pounds of nutrients added or removed from water runoff per year	Avoided cost of implementing conventional water treatment infrastructure, measured in dollars per pound of nutrients removed		x
Air quality	Tons of particulate matter (PM) added or removed from the atmosphere per year	Added property value, measured in percentage increase of property value per household per ton of particulate matter (PM) removed from the air		x
Carbon sequestration	Tons of carbon dioxide sequestered or emitted per year	Market value of carbon, measured in dollars per ton sequestered in a carbon market		x
Local climate control	Avoided kilowatt hours of air conditioning per year	Avoided electricity cost in air conditioning or heating per year, measured in kilowatt hours	x	x
Water retention	Gallons of water runoff stored or generated per year	Avoided costs of implementing bioretention practices, measured in dollars per gallon retained	x	x
Soil retention	Tons of soil conserved or released per year	Avoided cost of replacing topsoil, measured in dollars per cubic yard	x	

IV. RECOMMENDATIONS ON AN ECOSYSTEM SERVICE FRAMEWORK FOR MANAGED LANDSCAPES

A proposed conceptual framework

An important first step in operationalizing the quantification and valuation of ecosystem services for managed landscapes is to develop a framework that describes the process and inputs for conducting the analysis.

A proposed framework for identifying, quantifying, and valuing ecosystem services from these landscapes is presented in Figure 1. This framework builds upon the work of Boyd and Banzhaf (2006) advocating for consistently defined units of account to measure ecosystem services, and the EPA Science Advisory Board report on "Valuing the Protection of Ecological Systems and Services" (2009). The framework is comprised of three steps:

1. **Identify ecosystem services of strategic importance** and where possible, specify the cause and effect relationships among design features, management practices, and key services.
2. **Quantify ecosystem services** by choosing metrics and methods of quantification, and executing quantification. This step could inform development of performance metrics for sustainability initiatives.
3. **Value benefits of ecosystem services** by classifying each ecosystem service as providing value to private owners, and/or to the broader public, and executing valuation of ecosystem services. This step could enable decision makers to weigh the costs and benefits of different management practices and ultimately optimize a range of ecosystem services.

FIGURE 1

PROPOSED ECOSYSTEM SERVICES FRAMEWORK FOR MANAGED LANDSCAPES

1. IDENTIFY ECOSYSTEM SERVICES OF STRATEGIC IMPORTANCE	2. QUANTIFY ECOSYSTEM SERVICES	3. VALUE BENEFITS OF ECOSYSTEM SERVICES
Identify ecosystem services potentially affected by landscape design, construction, and management, which will need to be valued.	Choose metrics and methods of quantification by drawing on environmental models, tools, and peer-reviewed studies.	Classify each key ecosystem service as providing value to private resource owners, and/or the broader public. This avoids double counting or omission of benefits.
Where possible, specify the cause and effect relationships among design features, management practices, and key ecosystem services.	Quantify the flow of ecosystem services from the landscape.	Use economic valuation methods that meet appropriate validity criteria.

Practitioners interested in more technical details of such a framework and guidance on implementing it can refer to the white paper by Cardno ENTRIX entitled *A Framework to Quantify and Value Turfgrass Ecosystem Services* (MacNair et al. 2013). This white paper describes the appropriate methods, strengths, and limitations of possible ecosystem service quantification and valuation for managed landscapes, using the specific example of urban turfgrass.

Looking ahead

In order to further elaborate this framework, stakeholders should discuss and test it, working toward a standard, accepted framework to evaluate managed landscapes and the ecosystem services they provide. These groups should publicly share their experiences, addressing how they integrated ecosystem service considerations into decision making, what obstacles they faced, how they overcame them, how landscape management and performance changed, and what business and community benefits were achieved.

As the framework develops into a more technical and functional decision support tool, it will need to fit the decision context of landscape managers, landscape sustainability initiatives, and government bodies that have a stake in how these landscapes are designed and managed. To be useful and credible in this decision context, the framework should be:

COMPREHENSIVE

- Contributing a new lens that unites the environmental, social, and economic values flowing from the landscape
- Allowing practitioners to examine how ecosystem services generated on-site can affect surrounding areas beyond the fence line
- Considering the distribution of costs and benefits across stakeholders--both private landowners and surrounding communities.

POLICY-RELEVANT

- Based on sound science and economics
- Outcomes-focused and results-oriented, rather than utilizing practice-based measures of sustainability
- Using metrics and data that are defensible and easily obtainable (see Boyd and Banzhaf 2006; Layke 2009 for examples).

USEFUL FOR BENCHMARKING AND COMMUNICATIONS

- Including metrics that are sensitive to change due to changes in management decisions
- Considering the design, construction, and management phases of the landscape lifecycle, not just management practices.

Eventually, methodologies used to estimate ecosystem services performance should be standardized to ensure they are accurate and widely applicable. A standard framework will be useful in the following ways:

- **Landscape architects, designers, and managers** can use the framework to identify opportunities to reduce operational or compliance costs, find new revenue streams, improve marketability, and generate community good will by providing ecosystem services that are important to surrounding communities.
- **Groups involved in landscape sustainability initiatives** can use the framework to measure the ecosystem services flowing from a specific landscape, in a standardized and comparable way. This could enable performance benchmarking on an array of new, important sustainability parameters.
- **Local governments and environmental regulating bodies** can set the conditions that will enable ecosystem service management and protect the environmental and social assets important to communities.

Identifying, quantifying, and valuing the key ecosystem services flowing from a landscape will equip decision makers with a deepened knowledge of the landscape's environmental, social, and economic potential. Empowered with quantified ecosystem service benefits, planners and property owners will be able to identify ecosystem management practices and incentives that enable ecosystem services to generate environmental, economic, and social value.

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