

Metro Nature, Environmental Health, and Economic Value

Kathleen L. Wolf and Alicia S.T. Robbins

College of the Environment, University of Washington, Seattle, Washington, USA

BACKGROUND: Nearly 40 years of research provides an extensive body of evidence about human health, well-being, and improved function benefits associated with experiences of nearby nature in cities.

OBJECTIVES: We demonstrate the numerous opportunities for future research efforts that link metro nature, human health and well-being outcomes, and economic values.

METHODS: We reviewed the literature on urban nature-based health and well-being benefits. In this review, we provide a classification schematic and propose potential economic values associated with metro nature services.

DISCUSSION: Economic valuation of benefits derived from urban green systems has largely been undertaken in the fields of environmental and natural resource economics, but studies have not typically addressed health outcomes. Urban trees, parks, gardens, open spaces, and other nearby nature elements—collectively termed metro nature—generate many positive externalities that have been largely overlooked in urban economics and policy. Here, we present a range of health benefits, including benefit context and beneficiaries. Although the understanding of these benefits is not yet consistently expressed, and although it is likely that attempts to link urban ecosystem services and economic values will not include all expressions of cultural or social value, the development of new interdisciplinary approaches that integrate environmental health and economic disciplines are greatly needed.

CONCLUSIONS: Metro nature provides diverse and substantial benefits to human populations in cities. In this review, we begin to address the need for development of valuation methodologies and new approaches to understanding the potential economic outcomes of these benefits.

CITATION: Wolf KL, Robbins AS. 2015. Metro nature, environmental health, and economic value. *Environ Health Perspect* 123:390–398; <http://dx.doi.org/10.1289/ehp.1408216>

Introduction

More than 50% of the world's population now live in cities and further concentration in urban areas is forecast (United Nations Population Fund 2007). Although some city governments struggle to meet basic daily needs such as safe housing, dependable utilities, and transportation, many others have achieved reliable and affordable basic systems and services. Of interest to both governments and citizens, once basic systems are in place, is the livability of urban areas and the quality of life afforded their citizens. Residents of highly urbanized centers often expect livable environments that include access to urban nature and investments in green infrastructure.

The public has long recognized that nature in cities and towns provides beauty and respite. There is now extensive evidence that both constructed and endemic nature elements can contribute significant ecosystem services (ES) that generate public health co-benefits. Services such as air and water purification, stormwater management, carbon sequestration, and reduction of heat island effects are fairly well-defined at this time (Chen and Jim 2008), and have been assessed for their potential economic values (Nowak et al. 2010). The psychosocial services provided by metro nature are of increasing interest, including the cognitive, emotional, and psychological benefits derived from interactions with nature (Bratman et al. 2012).

Consistent with the articulation of ES by the Millennium Ecosystem Assessment (2005), various programs [such as The Economics of Ecosystems and Biodiversity (TEEB) (Sukhdev et al. 2014) and Earth Economics (Schrier et al. 2013)] and systems models (e.g., Reis et al. 2013; Rounsevell et al. 2010) have addressed the complexity of macro-ecological conservation in relation to human health, including concerns of biodiversity and climate change. Embedded within these more broadly scoped ecological management pursuits are the micro-scale nature elements that can permeate the urban environment.

Micro-scale nature elements can take many forms. The term “metro nature” is used here to refer to the collective opportunities for human nature experiences that improve urban livability (Wolf 2008). The term “metropolis,” from which “metro” is derived, refers to an urbanized area made up of multiple settlements and political jurisdictions. Metro nature is a unifying concept that acknowledges cultural and ecological landscapes governed by diverse entities and landowners—both public and private—within cities. Metro nature includes endemic ecosystems, such as urban forests, greenbelts, conserved open spaces, and riparian corridors that may be patch, relic, or feral expressions of native ecological associations. It also includes culturally constructed nature such as parks, streetscapes, community gardens, pocket parks, and recreation paths. Finally,

metro nature includes structural innovations that are integrated within built form to serve specific functions, such as green roofs, green walls, or green infrastructure facilities.

Recent studies have explored the definition and supply of urban ES. Papers about urban ES often represent a limited view of urban cultural aspects (Bolund and Hunhammar 1999; Gómez-Baggethun and Barton 2013; Larondelle and Haase 2013; Sander and Haight 2012) or have overlooked cultural values altogether (Jansson 2013; Li and Wu 2013). To date, the presentation and classification of urban ES does not adequately capture the full range of nature-based benefits and services within metro environments, particularly cultural ES (Wolf 2012).

The objective of this review was to demonstrate the extensive opportunities for research efforts that link metro nature, human health and well-being outcomes, and economic values. We begin by proposing a classification schematic that interprets a broader definition of ecosystem services, particularly cultural services, from an urban perspective. Methodologies for potential economic valuations of metro nature benefits are identified. We then review publications on urban nature-based benefits, summarized using the schematic. Our intent is to build on previous works that have initiated economic valuation of metro nature services and provide descriptions of a collection of human health and well-being benefits that may be readily expanded to include economic consequences. We also integrate current and future valuation opportunities.

Metro Nature and Health

Metro nature services are provided by small-scale nearby nature in neighborhoods and communities, and may be below the consciousness of individuals. The scientific

Address correspondence to K.L. Wolf, College of the Environment, Box 352100, University of Washington, Seattle, WA 98195 USA. Telephone: (206) 780-3619. E-mail: kwolf@uw.edu

S. Grado and M. Measells of the Forest and Wildlife Research Center at Mississippi State University provided input for the manuscript.

Support was provided by the U.S. Department of Agriculture (USDA) Forest Service, Urban and Community Forestry Program on the recommendation of the National Urban and Community Forestry Advisory Council and by the USDA Forest Service, Pacific Northwest Research Station.

The authors declare they have no actual or potential competing financial interests.

Received: 3 February 2014; Accepted: 26 January 2015; Advance Publication: 27 January 2015; Final Publication: 1 May 2015.

evidence of such services spans nearly 40 years and includes the contributions of diverse disciplines (Wolf 2012). An ongoing review of publications about the relationship between urban greening and human health and well-being has revealed more than a dozen themes of services and benefits, supported by > 3,000 scholarly publications (University of Washington 2014). In this review we used an iterative search process across major web search engines—such as PubMed (<http://www.ncbi.nlm.nih.gov/pubmed/>), JStor (<http://www.jstor.org/>), and Science Direct (<http://www.sciencedirect.com/>)—and key journals of disciplines that are active in benefits science, such as public health, environmental psychology, and natural resources. The references we collected are peer-reviewed articles that report either passive or active experiences with nearby nature and related outcomes of health and well-being. The thematic sorting was based on a content analysis of an initial collection of 300 articles.

We propose a classification schematic (Figure 1) to summarize the broad array of services and benefits provided by metro nature and demonstrated in the literature described above. In this section we introduce the framework components; below we provide citations about benefits and valuation potential that expands on recent surveys of cultural values (Chan et al. 2012; Daniel et al. 2012), particularly within the context of urban environments.

“Environmental fitness” is the baseline condition of environmental support for human health. Best practices and systems of a sanitary city provide the most basic conditions necessary for good health for all city residents, such as clean air and water, and the absence of toxicants (Pincetl 2010). Environmental protection agencies at national and regional levels may monitor and regulate potential harmful impacts from pollutant emissions, harmful materials dumping, and industrial and agricultural by-products. Urban forestry and green infrastructure are increasingly utilized as prevention or mitigation strategies within both regulatory and voluntary programs of urban sustainability.

“Wellness support” represents a less fundamental, but no less important, urban condition. Recent research efforts indicate that having ubiquitous green systems such as parks, community gardens, trees, and green spaces provides supplemental benefits. Convenient and pervasive access to nearby nature includes passive views from homes and vehicles, green spaces within walkable distances, and active encounters with nature (such as gardening and tree planting); all are scientifically linked to wellness. Beneficial human responses include physical activity that can reduce incidences of chronic diseases, physiological stress

moderation, and improved mental health. For instance, urban forest canopy proximate to households has been associated with higher infant birth weight (Dadvand et al. 2012) and green urban neighborhoods with reductions in elder mortality (Takano et al. 2002).

“Supportive spaces and healing places” entails more specific human responses. Common to the urban human experience are facilities and institutions where one conducts exacting routine activities (such as school or the workplace). Studies have found that nature is supportive in human performance situations as evidenced by improved workplace satisfaction (Kaplan 1993) and high school success (Matsuoka 2010). Landscape design or retention might be strategically placed to improve human function. Second, a more extensive literature has described how both passive experiences of nature and directed horticulture therapy can aid people in both physical and emotional healing. Such places include healing gardens within hospitals, horticulture therapy gardens, and sacred spaces (such as memorials). Landscapes that aid in healing or therapy are often dedicated constructed sites that include specific design elements intended to engage people for specified experiences or outcomes. In contrast, supportive spaces are expressions of nature that are adjacent to and augment places where people work, learn, or study; they provide benefits but not necessarily with the direct intention of healing places.

“Amenity and aesthetics” describes perhaps the most widely perceived benefit of trees, parks, and greening. Many in the green industries rely on client appeals of emotion and beauty, such as the Love Your Landscape messaging (Professional Landcare Network 2014). The City of Seattle, Washington (Seattle ReLeaf 2013) conducted marketing research to develop residential outreach to boost forest canopy cover; citizen responses of beauty, wonder, and spiritual connection to trees were more common than responses directed toward ecological services. Research indicates that humans respond to the presence of nature in profound ways, even after only brief exposure times, although they may not be directly aware of the outcomes. Neuroscience studies are considering the role of urban environmental influences on human wellness (Lederbogen et al. 2011).

Finally, the term “community” acknowledges that all of these experiences and associated services are embedded within the context of human systems, built places, and change. Citizens are becoming ever more involved in metro nature planning, implementation, and management. In resurgent cities, cleaning up vacant lots, restoring parks, and creating community gardens are often markers of community recovery (Harnik 2010). These

acts of civic ecology can lead to social engagement and cohesion, perhaps improving local social resilience (Krasny and Tidball 2012). Studies that address neighborhoods or general human populations have suggested that nature-based activity develops social foundations that can support disaster recovery (Tidball and Krasny 2014). Additional studies point to the unequal distribution of parks and natural resources within cities and its environmental justice implications (Jennings et al. 2012; Masuda et al. 2012).

Metro nature services are potentially available to all urbanites, and any single site may provide multiple functions, as shown in Figure 1. For instance, a hospital healing garden may be used for patient-healing activities as well as a restorative setting for staff breaks. Community investment is necessary to achieve optimal levels of all such services. Yet few metro nature services have been framed in terms of their potential economic values. Defining the broadest range of economic values associated with the human health and well-being benefits of metro nature can provide decision makers and urban planners with important information when making decisions about investments in these public goods.

Economic Methods

A number of methods are used to estimate the economic or monetary value of environmental attributes, with textbooks and journals devoted to the endeavor. The health economics field is similarly well-defined. Some approaches are used across both fields, including avoided or replacement costs, as well as decision-analysis frameworks such as benefit–cost, cost effectiveness, and cost utility. Stated preference methods were developed in environmental economics but are becoming more widely used in the medical economics literature. Only a brief overview of the methods suggested below is presented



Figure 1. Schematic of metro nature services and benefits.

here in order to introduce concepts to readers who may be unfamiliar with their use. For more in-depth methodological explanations of these and other environmental economic methods see, for example, Champ et al. (2003) or Tietenberg and Lewis (2011); other examples have been published in the health economics literature (e.g., Culyer and Newhouse 2000; Drummond et al. 2005).

Where markets exist, prices for goods and services are used to estimate value. Factor income approaches can be used where an improvement to a resource results in an increase in incomes derived from the resource. Production functions can be estimated when resources are used as inputs to the production of goods and services and where changes to the inputs result in production changes. Cost methods include several approaches. The avoided cost method uses monetary expenditures that would be avoided by employing specific management decisions or practices.

Many ecosystem services and benefits carry no market prices, so quantifying their economic value is performed through analysis of observed or hypothetical behaviors. Hedonic pricing uses sales prices of buildings or properties to isolate the differential effect of environmental attributes on property values. The contingent valuation method, originally developed to value public goods and services, asks survey respondents to identify willingness to pay for improvements—or willingness to accept damages—to a resource (Carson 2011). Similarly, discrete choice experiments also elicit willingness to pay and willingness to accept, but can include multiple levels of attributes at different cost levels; results can be used to create a ranking of preferences for alternative conditions or scenarios. Discrete choice experiments are well-established in the environmental economics literature and are increasingly being applied in the health economics field (Carson and Louviere 2010).

Decision-making frameworks in the fields of environmental and resource economics typically employ more than one estimation method to capture all benefits and costs. Benefit–cost analysis calculates total realized and expected benefits and costs of a project or conditions over time and discounts them to net present value, with the goal of identifying the option(s) that will provide the greatest net benefit. Cost-effectiveness analysis compares the relative benefits and costs of multiple means to meet the same goal by identifying cost differentials associated with different approaches. The option that meets the objective for the least cost is selected.

Health economics methods center on the cost of illness and treatment. Many of the methods described above can be applied to disease prevention and therapies. In addition, cost-minimization methods are frequently

employed. Evaluations are performed using decision-making frameworks. Value of statistical life represents the aggregation of individuals' willingness to pay to reduce the incidence of preventable death across a population. Burden of illness methods estimate the economic burden of diseases and potential savings associated with disease eradication. Quality-adjusted life-year techniques provide a measure of the number and quality of life years added by medical treatments and disease prevention.

Benefits and Economic Valuation: Literature to Date and Beyond

In this section we review existing literature on economic valuation of health and well-being benefits, and present benefits that have not been valued to date but warrant exploration. In these instances, benefits are defined and potential valuation methods suggested. The range of benefits is discussed in terms of the Figure 1 schematic.

Environmental fitness. Air pollution. Air quality improvements and CO₂ sequestration by vegetation can be expressed in monetary terms. Nowak et al. (2006) modeled total air pollution removal by urban trees and shrubs across 55 U.S. cities at 711,000 metric tons, estimating the removal value at \$3.8 billion in annual public value. Escobedo et al. (2008) quantified particulate matter removal by urban forests in Santiago, Chile, and estimated associated management costs. They compared their results with benefit estimations produced by the World Bank and found that managing urban forests to produce air quality improvements was a cost-effective approach to reducing particulate matter.

Stormwater runoff. Reduction of stormwater runoff can be achieved through planting or conserving existing forested areas and creating other green infrastructure mechanisms, such as green roofs (Mentens et al. 2006). Trees and soils improve water quality in that they can remove harmful substances washed off roads, parking lots, and roofs during rain or snow events. Vegetation can also reduce the need for costly stormwater treatment by retaining or slowing the flow of precipitation reaching the ground. These systems reduce the risk of major flooding and water treatment costs. In addition, vegetation can be planted to reduce the risk of negative effects from drought. The U.S. Environmental Protection Agency's (EPA) National Stormwater Calculator (<http://www2.epa.gov/water-research/national-stormwater-calculator>) can be used to estimate annual stormwater runoff, based on site-specific information. Other tools are available from the U.S. Department of Agriculture Forest Service to calculate ecosystem services provided by an

urban forest canopy (i-Tree Eco; <http://www.itreetools.org/>) or by street trees (i-Tree Streets; <http://www.itreetools.org/streets/index.php>). Analysis modules have been used to quantify multiple services (including air pollutant filtration, stormwater runoff reduction, carbon sequestration) (McPherson et al. 2005; Nowak et al. 2010; Soares et al. 2011). In some instances, monetary values have been estimated, for example, by calculating avoided or replacement costs using the difference in cost between traditional gray infrastructure installations and green infrastructure installations (Nowak and Dwyer 2007; U.S. EPA 2013).

Heat effects. One much-studied service provided by urban trees is canopy cover and shade, which in turn keeps people and buildings cooler and protected from extreme weather effects. Heat waves (and associated extreme nighttime temperatures) have been associated with detrimental health effects and excess mortality (Bowler et al. 2010). Urban forests and green roofs can aid in reducing urban heat island effects (Takebayashi and Moriyama 2007). Parks can be up to 2°F cooler than the surrounding urban area in the day (Bowler et al. 2010); large numbers of trees and expansive green spaces across a city can reduce local air temperatures by up to 9°F (McPherson 1994).

Noise abatement. There is now extensive evidence demonstrating the many negative effects of noise on health (Passchier-Vermeer and Passchier 2000). Trees and shrubs can significantly reduce noise (Fang and Ling 2003; Nowak et al. 2010). Noise and noise reduction effects on property prices have been studied, although not extensively, largely through the use of hedonic models (Day et al. 2007; Kim et al. 2007; McMillan et al. 1980). We found no studies specifically on noise abatement and economic values achieved through the use of trees, shrubs, or other green elements. Opportunities exist to use hedonic or other approaches that value aesthetic amenities. Combined approaches that use both revealed methods and choice experiments or the contingent valuation method might be also suited to this area of study.

Wellness support. Active living. Although studies are not consistent, research has demonstrated an association between parks and open spaces and the propensity to engage in physical activity (Ellaway et al. 2005; Giles-Corti et al. 2005). One research focus is the role home location and park proximity may play in physical activity, with mediating factors including the characteristics of routes to a park (Sugiyama et al. 2010). Schipperijn et al. (2013) reported that greater attention is now given to park attributes that promote activity. In establishing a relationship between physical activity and green space, it is important to specifically identify the type of activity

undertaken (de Vries et al. 2011), site features that enable or discourage activity, frequency of green space use, and other potentially confounding factors. Links between physical activity in or near green spaces and specific health outcomes are beginning to be explored. Although findings have been mixed, outcomes include obesity reduction (Lachowycz and Jones 2011; Potwarka et al. 2008), lower blood pressure (Hartig et al. 2003), and extended life spans (Takano et al. 2002).

Economic valuations are preliminary, appearing mostly in gray literature. The Trust for Public Land (2013) calculated annual avoided costs of health care associated with levels of physical activity in parks across 10 U.S. cities and counties; values ranged from \$4 million to \$69.4 million per year. The Green Infrastructure Toolkit provides a calculator for estimating reduced mortality due to increased walking in new green areas in cities in the United Kingdom (Natural Economy Northwest 2011). Willis and Crabtree (2011) presented potential methods for estimating the monetary value of reduced human mortality, morbidity, and averted deaths associated with physical activity in green space; they concluded that calculating net benefits of additional green space is dependent on identifying the degree of change from sedentary to active behavior. Discrete choice experiments allow the concomitant evaluation of multiple attributes and seem particularly appropriate for research questions that require simultaneously addressing both environmental and health factors. Potential cost savings estimates could be used in cost-effectiveness or benefit-cost analyses to examine tradeoffs between building locations or enhancing green space.

Stress relief. Studies have shown that relaxation and stress reduction are associated with exposure to green views (Kahn et al. 2008; Ulrich et al. 1991) and spending time or exercising in green areas (Hansmann et al. 2007; Hartig et al. 2011), including walking in forested areas (Park et al. 2010; Tsunetsugu et al. 2010). Stress response is a contributor to short- and long-term physiological outcomes: sleep loss, suppressed immune system function, susceptibility to illness, high blood pressure, cardiovascular disease, stroke, and diabetes (National Center for Health Statistics 2001). Cost approaches could include identifying treatment reductions or alternatives that reduce burden of illness. Similarly, cost-effectiveness analysis could be employed to estimate intervention tradeoffs once treatment alternatives are identified.

Mental health. Recent studies highlight the importance of nature contact for general mental health. Aspinall et al. (2015) reported that when respondents moved into a green space zone, their electroencephalography (EEG) recorder data showed lower frustration,

attentional engagement, and arousal, but higher meditation. People living in urban areas with greater amounts of green space showed significantly lower mental distress (White et al. 2013). In a study about mental health responses and green space, Annerstedt et al. (2012) found a reduced risk for poor mental health among women (but not men) through a significant interaction effect between physical activity and access to certain qualities. In a study of individuals with major depressive disorders, Berman et al. (2012) found improvements in mood associated with walking in nature. Reduced depression in the elderly after walking in gardens has been reported (Blumenthal et al. 1999; McCaffrey et al. 2010). Outdoor spaces designed for walking have also been associated with lowering symptoms of Alzheimer's and dementia (Chalfont and Rodiek 2005; Mooney and Nicell 1992). Research is still needed to explore the potential for green spaces to supplement or be used instead of professional therapy or prescription medicine. Avoided-cost or cost-effectiveness methods might be used to estimate reductions in care costs or cost tradeoffs.

Urban food and foraging. Urban community gardens, rooftop vegetable gardens, and public orchards are examples of urban ecosystem goods production (McLain et al. 2012a). These "edible landscapes" rarely provide adequate food supplies for local urban populations (Armstrong 2000). However, they can be important sources of food to specific populations (McGranahan et al. 2005) and can support food resilience in some situations (Barthel and Isendahl 2013). In addition, recent assessments of urban gathering and foraging show that urban forests contain nontimber forest products that contribute a variety of wild foods, medicines, and materials useful for the well-being of urban residents, with some materials (such as culinary fungi) supporting household livelihoods (McLain et al. 2012b; Poe et al. 2013). Although many studies have noted the absence of adequate food sources in some inner-city areas (Walker et al. 2010), little economic valuation of urban agriculture or foraging has been done to date. One study found that the presence of community gardens had a positive impact on property values, particularly in poorer neighborhoods (Voicu and Been 2008). In areas with organized community gardens, such as those overseen by city governments, there could be opportunities to estimate production functions and value, as well as factor income effects, perhaps on a micro-community level.

Respiratory health. Findings on the links between respiratory health and vegetation or canopy cover in urban areas are mixed. Donovan et al. (2013) found a correlation between residential tree loss (due to emerald

ash borer-related tree mortality) and respiratory disease. Lovasi et al. (2008) reported that street trees in New York City were associated with a lower prevalence of early childhood asthmas, but the results were questioned by Zandbergen (2009). Pilat et al. (2012) did not find statistically significant relationships between vegetation and canopy cover and childhood asthma in Texas. Further evidence on links between the presence of trees and other green elements with respect to respiratory health is needed to establish net benefits. These could then be translated into economic terms through the use of avoided-cost or cost-effectiveness methods to estimate reductions in care costs or cost tradeoffs associated with reduced respiratory illness and disease. Value of statistical life or quality-adjusted life-year methods could be used to measure the value of respiratory-related mortality risk reduction.

Supportive spaces. Mental function. The directed cognitive focus that is needed for task attention (in school or at work) can be improved after exposure to nature (Kaplan R 1993; Kaplan S 1995; Lohr et al. 1996; Shibata and Suzuki 2002). Studies show that improved employee morale, decreased absenteeism, and increased worker efficiency result from nature experiences while in the workplace (Lohr et al. 1996). Having plants within view of workstations decreases illness incidence (Fjeld et al. 1998) and the amount of self-reported sick leave, and boosts workplace satisfaction (Kaplan 1993). Not having nature views or indoor plants may be associated with higher levels of tension and anxiety in office workers (Chang and Chen 2005). In academic settings, nature views may lead to improved high school and college student performance (Matsuoka 2010; Tennesen and Cimprich 1995). More research is needed on individuals' academic achievement or school rankings (e.g., test scores, graduation rates, college enrollment). Differences in graduation rates and college attendance could be associated with annual or lifetime earnings. In workplace settings, decreased absenteeism or increased productivity in the workplace could be associated with a mean or median wage level or with increased revenue or efficiency for companies.

Attention deficit disorder (ADD). Research has shown that when children are engaged in activities in green settings, childhood ADD symptoms are reduced (Taylor and Kuo 2011; Taylor et al. 2001) and concentration abilities are improved (Kuo and Taylor 2004). Spending time in green settings may be an important supplement to established drug-based and behavioral treatments (Taylor and Kuo 2009). Again, avoided-cost or cost-effectiveness methods could be used to estimate the reductions in medication and care costs or cost tradeoffs. As noted above

for mental function, improved educational attainment and school performance could be linked to increased lifetime earnings.

Healing spaces. Physical healing. Recent research has shown that access to natural elements can aid physical healing (Sherman et al. 2005; Walch et al. 2005). Studies have reported faster surgical recovery and patient healing in hospitals (Park and Mattson 2009; Ulrich 1984) and higher pain thresholds (Diette et al. 2003; Tse et al. 2002) associated with passive nature experiences and views. One hypothesis is that nature serves as a distraction that allows individuals to refocus cognitive effort, resulting in increased pain thresholds and tolerance as well as improved coping and healing (Ulrich 1999). Another hypothesis posits that exposure to green attributes in hospitals helps to reduce cognitive stress levels (Kaplan and Kaplan 1983), which can be linked to negative health outcomes (Varni and Katz 1997). This research has prompted some hospitals to establish healing gardens (Cooper Marcus and Sachs 2013; Franklin 2012) and provide horticulture therapy programs.

Ulrich (1984) found that patients having a view of nature during surgery recovery had, on average, a 1-day shorter hospitalization stay; this is significant given the daily cost of hospital stays, which average about \$1,700 in the United States (Aetna 2013). More data are needed to verify dose responses and determine how exposure to green spaces affects both in-patient and out-patient treatments, with potential reduced or avoided costs. Another method that could be applied is willingness to pay for pain-reduction treatments. Discrete choice methods could be used to survey patients with different treatment options in regard to pain levels or recovery times (Chuck et al. 2009). Quality-of-life metrics could also be used. All valuation approaches could be compared with implementation costs and used in decision-making in terms of benefit–cost tradeoffs and cost effectiveness.

Horticulture and nature therapy. Nature-based therapies typically incorporate garden activities such as design and planting, maintenance, or visitation. Therapeutic horticulture is the creation of settings and/or activities that enrich participants' lives through interactions with the diversity of life in the natural world. Horticultural therapy is the use of an intervention or prescribed activity to address specific, diagnosed emotional and physical disabilities; activities take place in gardens and established outdoor restorative centers (American Horticultural Therapy Association 2013). In preliminary studies of gardens and nature therapy, elderly participants have reported pain reduction, improvement in attention, reduced stress, modulation of agitation, lowered need for medications

and antipsychotics, and reduction of falls (Detweiler et al. 2012). Additional outcomes have included improvements for those experiencing chronic mental illness (Perrins-Margalis et al. 2000), clinical depression (Gonzalez et al. 2010), posttraumatic stress disorders (Lorber 2011), maternity care (Browning and Lee 2011), and autism (Flick 2012), and for those being served in acute health care settings (Hilbers and Satharasinghe 2013) or crisis centers (Lygum et al. 2012). Horticultural programs in prisons in the United States suggest decreased hostility (Rice and Remy 1998), reduced recidivism (Jiler 2009), and better social adjustment for juvenile offenders (McGuinn and Relf 2001). Nature therapy could be used in lieu of prescription medicine or may lead to a reduction in overnight stays or in prison costs. Lee et al. (2008) used the contingent valuation method for such valuations; other approaches might be cost effectiveness and burden of illness metrics.

Amenities and aesthetics. Numerous studies have estimated impacts of street trees, urban parks, and open space on property prices. Hedonic approaches are particularly common. Although studies use various specific measurements of tree cover and examine values that differ across urban locations, findings generally demonstrate a positive relationship between the proximity to green spaces, such as urban parks and forest reserves, and property prices (Anderson and West 2006; Dombrow et al. 2000; Donovan and Butry 2010; Sander et al. 2010; Thorsnes 2002). Landscape aesthetics may also positively impact spending in retail areas. Studies using stated preference methods studies have found that consumers may be inclined to spend more while shopping in districts that have quality tree canopies (Wolf 2014). In addition, there is evidence that urban forests and parks may play a significant role in attracting tourism and associated revenue (Deng et al. 2010; Majumdar et al. 2011).

Community. Crime and safety. Several studies have examined associations between crime and vegetation, with mixed results. Early studies focused on the perceived threats created by vegetation (Michael et al. 2001; Nasar and Fisher 1993), such as concealment and reduced sight lines. More recently, studies have shown how vegetation can contribute to reductions in domestic aggression and violent behaviors (Kuo and Sullivan 2001); assault, robbery, and burglary (Wolfe and Mennis 2012); and theft (Troy et al. 2012). The type, height, and positioning of vegetation near single-family homes may have a positive effect on nonviolent crimes such as burglary and vandalism (Donovan and Prestemon 2012). Branas et al. (2011) found that greening of vacant lots in Philadelphia,

Pennsylvania, was associated with reduced gun assaults, vandalism and criminal mischief, and self-reported reductions in stress, and with increased exercise.

We found no studies that directly monetized the links between decreased crime and vegetation. The impacts of crime on property values have been widely established (Hellman and Naroff 1979; Rizzo 1979), but studies have not addressed the effects of vegetative cover and placement. Using a hedonic approach, Troy and Grove (2008) found that proximity to parks had a positive influence on property prices until crime rates reached a threshold, above which proximity to parks began to negatively influence property values. Further studies along these lines would be valuable. The value of reduced crime could also be examined as it affects community policing and law enforcement costs, as well as property insurance rates and premiums.

Discussion

The economic valuation of benefits derived from metro nature elements has largely been undertaken in the fields of environmental and natural resource economics, but these valuations do not typically address health and well-being outcomes. Expanded research effort in the development of new interdisciplinary approaches that integrate environmental and health economics is greatly needed. Here we have presented many such opportunities.

The literature on public health economics is dominated by cost-effectiveness and cost-minimization approaches, both of which can be similarly useful for evaluating tradeoffs between public health outcomes and the costs of creating or improving urban green infrastructure. Environmental economics often addresses negative externalities that are produced as a result of human activities such as air and water pollution and overfishing. The legacy of environmental health is to address concerns of toxicants and environmental risk; equally important is the potential for wellness from benevolent nature encounters (Frumkin 2001). Urban open spaces and elements create many positive externalities that have gone largely ignored, including the benefits of active living, physical healing, and mental restoration, among others.

It is important to acknowledge limitations to these efforts. Here we focused on the positive human response to metro nature elements, but there are certain to be associated costs. There are also potential disservices to urban ecosystems, such as air pollution and diseases from animals (Gómez-Baggethun and Barton 2013). Future analysis needs to address the cumulative per capita or regional balance of services to disservices. There may be overlapping benefits and interdependencies among benefits, discrepancies between payee

and beneficiary, and inter-temporal issues. Our intent was to identify a range of benefits; it is likely that ecosystem functions overlap. Finally, because investigations of urban benefits are in the early stages, it is likely that any attempt to link ES and economic values will necessarily be incomplete.

Although there is already considerable research demonstrating positive links between metro nature and public health, Frumkin (2012) pointed out that additional study is needed and many questions are still unanswered. For instance, what are the mechanisms through which nature contact improves health and well-being, how should it be delivered, and at what dose and for how long? Forthcoming studies will address these questions, but the science is nascent. Additional questions include the spatial and temporal dimensions of nature experience and response. Identifying the natural resource elements and relevant populations of benefit is paramount. This may be key to identifying both service and valuation potentials because land use designations (e.g., residential vs. institutional) can be indicative of potential populations and service. Furthermore, landscape treatment is an important consideration. Some benefits appear to be generated by the mere presence of tree canopy; others are dependent on the presence of more detailed and refined landscape treatments at greater cost.

Challenges

Empirical assessment of how urban forests and greenery affect health outcomes and quality of life poses analytical challenges because pathways linking the two are complex (Lachowycz and Jones 2013). There are direct effects where closeness to nature has intrinsic healing effects. Innate responses may be due to neuroanatomy (Kim et al. 2010), endocrine response (such as cortisol reduction), or para/sympathetic nerve system activity (Park et al. 2010). In contrast, some pathways include mediating conditions where urban greening either changes an exposure (such as air pollution) or behaviors (such as active use of trails) that lead to beneficial health outcomes. Measuring these contingencies involves pooling expertise from multiple disciplines, as well as assuring that all variables are commensurate in scale. Cross-sectional studies have limited applicability in drawing causal inferences between nature situations and health outcomes. Given that performing randomized control trials with urban nature interventions and health are practically infeasible (and perhaps unethical), statistical techniques (e.g., propensity-score matching) using natural experiments, as well as carefully designed case-control quasi-experimental studies are necessary to increase the evidence base on this issue.

Conclusions

Nearly 40 years of research provides a body of evidence about benefits of human health, well-being, and improved function associated with experiences of nearby nature in cities. Yet research methods and measures are diverse in concept and implementation, presenting important concerns and challenges for monetary translation.

Although it is not necessary to frame all health and well-being outcomes in monetary terms, doing so is often effective at capturing both the public's attention as well as that of governmental leaders and policy makers. Considering the importance of valuation in public policy and decision making, there may be value in developing a platform of common assessment that standardizes benefit measurement and nature units. Future research on benefits could then generate comparable findings as values for policy inputs across communities and metro areas.

Based on previous research, there is a clear need for development of valuation methodologies and new approaches to understanding the potential economic outcomes of these benefits. Many urban ES can be effectively provided to serve multiple public needs. When it can be shown that they have a true impact on health and quality of life, society may begin to appreciate and act on their full value.

REFERENCES

- Aetna. 2013. Hospital Stays Can Put a Strain on Your Personal Finances. Available: <http://www.aetna.com/voluntary/hospital.html> [accessed 29 December 2014].
- American Horticultural Therapy Association. 2013. American Horticultural Therapy Association Definitions and Positions. Available: <http://ahta.org/sites/default/files/DefinitionsandPositions.pdf> [29 December 2014].
- Anderson ST, West SE. 2006. Open space, residential property values, and spatial context. *Reg Sci Urban Econ* 36:773–789.
- Annerstedt M, Östergren PO, Björk J, Grahn P, Skärback E, Währborg P. 2012. Green qualities in the neighbourhood and mental health—results from a longitudinal cohort study in southern Sweden. *BMC Public Health* 12:337; doi:10.1186/1471-2458-12-337.
- Armstrong, D. 2000. A survey of community gardens in upstate New York: implications for health promotion and community development. *Health Place* 6:319–327.
- Aspinall P, Mavros P, Coyne R, Roe J. 2015. The urban brain: analysing outdoor physical activity with mobile EEG. *Br J Sports Med* 49:272–276; doi:10.1136/bjsports-2012-091877.
- Barthel S, Isendahl D. 2013. Urban gardens, agriculture, and water management: sources of resilience for long-term food security in cities. *Ecol Econ* 86:224–234.
- Berman MG, Kross E, Krpan KM, Askren MK, Burson A, Deldin PJ, et al. 2012. Interacting with nature improves cognition and affect for individuals with depression. *J Affect Disord* 140:300–305.
- Blumenthal JA, Babyak MA, Moore KA, Craighead WE, Herman S, Khatri P, et al. 1999. Effects of exercise training on older patients with major depression. *Arch Intern Med* 159:2349–2356.
- Bolund P, Hunhammar S. 1999. Ecosystem services in urban areas. *Ecol Econ* 29:293–301.
- Bowler DE, Buyung-Ali LM, Knight TM, Pullin AS. 2010. Urban greening to cool towns and cities: a systematic review of the empirical evidence. *Landsc Urban Plan* 97:147–155.
- Branas CC, Cheney RA, MacDonald JM, Tam VW, Jackson TD, Ten Have TR. 2011. A difference-in-differences analysis of health, safety, and greening vacant urban space. *Am J Epidemiol* 174:1296–1306.
- Bratman GN, Hamilton JP, Daily GC. 2012. The impacts of nature experience on human cognitive function and mental health. *Ann NY Acad Sci* 1249:118–136.
- Browning LM, Lee S. 2011. Pregnancy and place: creating therapeutic gardens for maternity care patients. *J Therap Hort* 21:42–67.
- Carson R. 2011. *Contingent Valuation: A Comprehensive Bibliography and History*. Cheltenham, UK:Edward Elgar Publishing.
- Carson RT, Louviere JJ. 2010. Experimental design and the estimation of willingness to pay in choice experiments for health policy evaluation. In: *Applied Methods of Cost-Benefit Analysis in Health Care* (McIntosh E, Clarke P, Frew EJ, Louviere JJ, eds). New York:Oxford University Press, 185–210.
- Chalfont GE, Rodiek S. 2005. Building edge: an ecological approach to research and design of environments for people with dementia. *Alzheimer's Care Q* 6:341–348.
- Champ PA, Boyle KJ, Brown TC, eds. 2003. *A Primer on Nonmarket Valuation*. Boston, MA:Kluwer Academic Press.
- Chan, KM, Satterfield T, Goldstein J. 2012. Rethinking ecosystem services to better address and navigate cultural values. *Ecol Econ* 74:8–18.
- Chang CY, Chen PK. 2005. Human response to window views and indoor plants in the workplace. *HortScience* 40:1354–1359.
- Chen WY, Jim CY. 2008. Assessment and valuation of the ecosystem services provided by urban forests. In: *Ecology, Planning, and Management of Urban Forests* (Carreiro MM, Song YC, Wu J, eds). New York:Springer, 53–83.
- Chuck A, Adamowicz W, Jacobs P, Ohinmaa A, Dick B, Rashiq S. 2009. The willingness to pay for reducing pain and pain-related disability. *Value Health* 12:498–506.
- Cooper Marcus C, Sachs NA. 2013. *Therapeutic Landscapes: An Evidence-Based Approach to Designing Healing Gardens and Restorative Outdoor Spaces*. New York:John Wiley & Sons.
- Culyer AJ, Newhouse JP. 2000. *Handbook of Health Economics*. New York:Elsevier.
- Dadvand P, Sunyer J, Basagaña X, Ballester F, Lertxundi A, Fernández-Somoano A, et al. 2012. Surrounding greenness and pregnancy outcomes in four Spanish birth cohorts. *Environ Health Perspect* 120:1481–1487; doi:10.1289/ehp.1205244.
- Daniel TC, Muhar A, Arnberger A, Aznar O, Boyd JW, Chan KM, et al. 2012. Contributions of cultural services to the ecosystem services agenda. *Proc Nat Acad Sci USA* 109:8812–8819.
- Day B, Bateman I, Lake I. 2007. Beyond implicit prices: recovering theoretically consistent and transferable values for noise avoidance from a hedonic property price model. *Environ Resource Econ* 37:211–232.
- Deng J, Arano KG, Pierskalla C, McNeel, J. 2010. Linking urban forests and urban tourism: a case of Savannah, Georgia. *Tourism Anal* 15:167–181.
- Detweiler MB, Sharma T, Detweiler JG, Murphy PF, Lane S, Carman J, et al. 2012. What is the evidence to support the use of therapeutic gardens for the elderly? *Psychiatry Investig* 9:100–110.

- de Vries S, Claßen T, Eigenheer-Hug SM, Korpela K, Maas J, Mitchell R, et al. 2011. Contributions of natural environments to physical activity: theory and evidence base. In: *Forests, Trees and Human Health* (Nilsson K, Sangster M, Gallis C, Hartig T, de Vries S, Seeland K, et al., eds). New York:Springer, 205–243.
- Diette GB, Lechtzin N, Haponik E, Devrotes A, Rubin HR. 2003. Distraction therapy with nature sights and sounds reduces pain during flexible bronchoscopy: a complementary approach to routine analgesia. *Chest* 123:941–948.
- Dombrow J, Rodriguez M, Sirmans CF. 2000. The market value of mature trees in single-family housing markets. *Appraisal J* 68:39–43.
- Donovan GH, Butry DT. 2010. Trees in the city: valuing street trees in Portland, Oregon. *Landsc Urban Plan* 94:77–83.
- Donovan GH, Butry DT, Michael YL, Prestemon JP, Liebhold AM, Gatzliolis D, et al. 2013. The relationship between trees and human health: evidence from the spread of the emerald ash borer. *Am J Prev Med* 44:139–145.
- Donovan GH, Prestemon JP. 2012. The effect of trees on crime in Portland, Oregon. *Environ Behav* 44:3–30.
- Drummond MF, Sculpher MJ, Torrance GW, O'Brien BJ, Stoddart GL. 2005. *Methods for the Economic Evaluation of Health Care Programmes*. 3rd ed. New York:Oxford University Press.
- Ellaway A, Macintyre S, Bonnefoy X. 2005. Graffiti, greenery, and obesity in adults: secondary analysis of European cross sectional survey. *BMJ* 331:611–612.
- Escobedo FJ, Wagner JE, Nowak DJ, De La Maza CL, Rodriguez M, Crane DE. 2008. Analyzing the cost-effectiveness of Santiago, Chile's policy of using urban forests to improve air quality. *J Environ Manage* 86:148–157.
- Fang CF, Ling DL. 2003. Investigation of the noise reduction provided by tree belts. *Landsc Urban Plan* 63:187–195.
- Fjeld T, Veiersted B, Sandvik L, Riise G, Levy F. 1998. The effect of indoor foliage plants on health and discomfort symptoms among office workers. *Indoor Built Environ* 7:204–209.
- Flick KM. 2012. The application of a horticultural therapy program for preschool children with autism spectrum disorder. *J Therap Hort* 22:38–45.
- Franklin D. 2012. Nature that nurtures. *Sci Am* 306:24–25.
- Frumkin H. 2001. Beyond toxicity: human health and the natural environment. *Am J Prev Med* 20:234–240.
- Frumkin H. 2012. Building the science base: ecopsychology meets clinical epidemiology. In: *Ecopsychology: Science, Totems, and the Technological Species* (Kahn PH, Hasbach PH, eds). Cambridge, MA:MIT Press, 141–172.
- Giles-Corti B, Broomhall MH, Knuiam M, Collins C, Douglas K, Ng K, et al. 2005. Increasing walking: how important is distance to, attractiveness, and size of public open space? *Am J Prev Med* 28(2 suppl 2):169–176.
- Gómez-Baggethun E, Barton D. 2013. Classifying and valuing ecosystem services for urban planning. *Ecol Econ* 86:235–245.
- Gonzalez MT, Hartig T, Patil GG, Martinsen EW, Kirkeveld M. 2010. Therapeutic horticulture in clinical depression: a prospective study of active components. *J Adv Nurs* 66:2002–2013.
- Hansmann R, Hug SM, Seeland K. 2007. Restoration and stress relief through physical activities in forests and parks. *Urban For Urban Gree* 6:213–225.
- Harnik P. 2010. *Urban Green: Innovative Parks for Resurgent Cities*. Washington, DC:Island Press.
- Hartig T, Evans GW, Jamner LD, Davis DS, Gärling T. 2003. Tracking restoration in natural and urban field settings. *J Environ Psychol* 23:109–123.
- Hartig T, van den Berg AE, Hagerhall CM, Tomalak M, Bauer N, Hansmann R, et al. 2011. Health benefits of nature experiences: psychological, social and cultural processes. In: *Forests, Trees and Human Health* (Nilsson K, Sangster M, Gallis C, Hartig T, de Vries S, Seeland K, et al., eds). New York:Springer, 127–168.
- Hellman DA, Naroff JL. 1979. The impact of crime on urban residential property values. *Urban Stud* 16:105–112.
- Hilbers J, Satharasinghe A. 2013. Gardens and therapeutic horticulture in an acute healthcare setting: opportunities provided by the Blooming Backyard project at Prince of Wales Hospital, Sydney. *J Therap Hort* 23:35–48.
- Jansson Å. 2013. Reaching for a sustainable, resilient urban future using the lens of ecosystem services. *Ecol Econ* 86:285–291.
- Jennings V, Johnson Gaither C, Gragg RS. 2012. Promoting environmental justice through urban green space access: a synopsis. *Environ Justice* 5:1–7.
- Jiler J. 2009. Restoring lives, transforming landscapes: the GreenHouse program at Rikers Island Jail. In: *Restorative Commons: Creating Health and Well-Being Through Urban Landscapes* (Campbell L, Wiesen A, eds). General Technical Report NRS-P-39. Newtown Square, PA:U.S. Department of Agriculture, Forest Service, Northern Research Station. Available: <http://www.nrs.fs.fed.us/pubs/gtr/gtr-nrs-p-39papers/13-jiler-p-39.pdf> [accessed 27 March 2015].
- Kahn PH Jr, Friedman B, Gill B, Hagman J, Severson RL, Freier NG, et al. 2008. A plasma display window? The shifting baseline problem in a technologically mediated natural world. *J Environ Psychol* 28:192–199.
- Kaplan R. 1993. The role of nature in the context of the workplace. *Landsc Urban Plan* 26:193–201.
- Kaplan S. 1995. The restorative benefits of nature: toward an integrative framework. *J Environ Psychol* 15:169–182.
- Kaplan S, Kaplan R. 1983. *Cognition and Environment: Functioning in an Uncertain World*. New York:Praeger Publishers.
- Kim GW, Jeong GW, Kim TH, Baek HS, Oh SK, Kang HK, et al. 2010. Functional neuroanatomy associated with natural and urban scenic views in the human brain: 3.0T functional MR imaging. *Korean J Radiol* 11:507–513.
- Kim KS, Park SJ, Kweon YJ. 2007. Highway traffic noise effects on land price in an urban area. *Transp Res Part D* 12:275–280.
- Krasny ME, Tidball KG. 2012. Civic ecology: a pathway for earth stewardship in cities. *Front Ecol Environ* 10:267–273.
- Kuo FE, Sullivan WC. 2001. Environment and crime in the inner city: does vegetation reduce crime? *Environ Behav* 33:343–367.
- Kuo FE, Taylor AF. 2004. A potential natural treatment for attention-deficit/hyperactivity disorder: evidence from a national study. *Am J Public Health* 94:1580–1586.
- Lachowycz K, Jones AP. 2011. Greenspace and obesity: a systematic review of the evidence. *Obes Rev* 12:183–189.
- Lachowycz K, Jones AP. 2013. Towards a better understanding of the relationship between greenspace and health: development of a theoretical framework. *Landsc Urban Plan* 118:62–69.
- Larondelle N, Haase D. 2013. Urban ecosystem services assessment along a rural–urban gradient: a cross-analysis of European cities. *Ecol Indic* 29:179–190.
- Lederbogen F, Kirsch P, Haddad L, Streit F, Tost H, Schuch P, et al. 2011. City living and urban upbringing affect neural social stress processing in humans. *Nature* 474:498–501.
- Lee CK, Park SA, Mjelde JW, Kim TK, Cho JH. 2008. Measuring the willingness-to-pay for a horticulture therapy site using a contingent valuation method. *HortScience* 43:1802–1806.
- Li W, Wu C. 2013. A spatially explicit method to examine the impact of urbanisation on natural ecosystem service values. *J Spat Sci* 58:275–279.
- Lohr VI, Pearson-Mims CH, Goodwin GK. 1996. Interior plants may improve worker productivity and reduce stress in a windowless environment. *J Environ Hort* 14:97–100.
- Lorber H. 2011. The use of horticulture in the treatment of post-traumatic stress disorder in a private practice setting. *J Therap Hort* 21:18–29.
- Lovasi GS, Quinn JW, Neckerman KM, Perzanowski MS, Rundle A. 2008. Children living in areas with more street trees have lower prevalence of asthma. *J Epidemiol Community Health* 62:647–649.
- Lygum VL, Stigsdotter UK, Konijnendijk CC, Højberg H. 2012. Outdoor environments at crisis shelters in Denmark. *J Therap Hort* 22:8–31.
- Majumdar S, Deng J, Zhang Y, Pierskalla C. 2011. Using contingent valuation to estimate the willingness of tourists to pay for urban forests: a study in Savannah, Georgia. *Urban For Urban Gree* 10:275–280.
- Masuda JR, Teelucksingh C, Zupancic T, Crabtree A, Haber R, Skinner E, et al. 2012. Out of our inner city backyards: re-scaling urban environmental health inequity assessment. *Soc Sci Med* 75:1244–1253.
- Matsuoka RH. 2010. Student performance and high school landscapes: examining the links. *Landsc Urban Plan* 97:273–282.
- McCaffrey R, Hanson C, McCaffrey W. 2010. Garden walking for depression: a research report. *Holist Nurs Pract* 24:252–259.
- McGranahan G, Marcotullio P, Bai XM, Balk D, Braga T, Douglas I, et al. 2005. Urban systems. In: *Millennium Ecosystem Assessment. Ecosystems and Human Well-being: Current State and Trends, Vol. 1* (Hassan R, Scholes R, Ash N, eds). Washington, DC:Island Press, 795–825.
- McGuinn CP, Relf PD. 2001. A profile of juvenile offenders in a vocational horticulture curriculum. *HortTechnol* 11:427–433.
- McLain RJ, MacFarland K, Brody L, Hebert J, Hurley P, Poe M, et al. 2012a. *Gathering in the City: An Annotated Bibliography and Review of the Literature about Human-Plant Interactions in Urban Ecosystems*. General Technical Report PNW-GTR-849. Portland, OR:U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Available: http://www.fs.fed.us/pnw/pubs/pnw_gtr849.pdf [accessed 29 December 2014].
- McLain R, Poe M, Hurley PT, Lecompte-Mastenbrook J, Emery MR. 2012b. Producing edible landscapes in Seattle's urban forest. *Urban For Urban Gree* 11:187–194.
- McMillan ML, Reid BG, Gillen DW. 1980. An extension of the hedonic approach for estimating the value of quiet. *Land Econ* 56:315–328.
- McPherson EG. 1994. Cooling urban heat islands with sustainable landscapes. In: *The Ecological City: Preserving and Restoring Urban Biodiversity* (Platt RH, Rowntree RA, Muick PC, eds). Amherst, MA:University of Massachusetts Press, 151–171.
- McPherson G, Simpson JR, Peper PJ, Maco SE, Xiao Q. 2005. Municipal forest benefits and costs in five US cities. *J For* 103:411–416.

- Mentens J, Raes D, Hermy M. 2006. Green roofs as a tool for solving the rainwater runoff problem in the urbanised 21st century. *Landsc Urban Plan* 77:217–226.
- Michael SE, Hull RB, Zahm DL. 2001. Environmental factors influencing auto burglary: a case study. *Environ Behav* 33:368–388.
- Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-Being: Synthesis*. Washington, DC: Island Press. Available: <http://www.millenniumassessment.org/documents/document.356.aspx.pdf> [accessed 27 March 2015].
- Mooney P, Nicell PL. 1992. The importance of exterior environment for Alzheimer residents: effective care and risk management. *Healthc Manage Forum* 5:23–29.
- Nasar JL, Fisher BS. 1993. 'Hot spots' of fear and crime: a multi-method investigation. *J Environ Psychol* 13:187–206.
- National Center for Health Statistics. 2001. *Healthy People 2000 Final Review*. DHHS Publication No. 01-0256. Hyattsville, MD: Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics. Available: <http://www.cdc.gov/nchs/data/hp2000/hp2k01.pdf> [accessed 29 December 2014].
- Natural Economy Northwest. 2011. *Building Natural Value for Sustainable Economic Development: the Green Infrastructure Valuation Toolkit User Guide*. Available: http://www.greeninfrastructurenw.co.uk/resources/Green_Infrastructure_Valuation_Toolkit_UserGuide.pdf [accessed 29 December 2014].
- Nowak DJ, Crane DE, Stevens JC. 2006. Air pollution removal by urban trees and shrubs in the United States. *Urban For Urban Gree* 4:115–123.
- Nowak DJ, Dwyer JF. 2007. Understanding the benefits and costs of urban forest ecosystems. In: *Urban and Community Forestry in the Northeast* (Kuser JE, ed). 2nd ed. New York: Springer, 25–46.
- Nowak DJ, Stein SM, Randler PB, Greenfield EJ, Comas SJ, Carr M, et al. 2010. *Sustaining America's Urban Trees and Forests: A Forests on the Edge Report*. General Technical Report NRS-62. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. Available: http://www.fs.fed.us/openspace/fote/reports/nrs-62_sustaining_americas_urban.pdf [accessed 29 December 2014].
- Park BJ, Tsunetsugu Y, Kasetani T, Kagawa T, Miyazaki Y. 2010. The physiological effects of *Shinrin-yoku* (taking in the forest atmosphere or forest bathing): evidence from field experiments in 24 forests across Japan. *Environ Health Prev Med* 15:18–26.
- Park SH, Mattson RH. 2009. Ornamental indoor plants in hospital rooms enhanced health outcomes of patients recovering from surgery. *J Altern Complement Med* 15:975–980.
- Passchier-Vermeer W, Passchier WF. 2000. Noise exposure and public health. *Environ Health Perspect* 108(suppl 1):123–131.
- Perrins-Margalis NM, Rugletic J, Schepis NM, Stepanski HR, Walsh MA. 2000. The immediate effects of a group-based horticulture experience on the quality of life of persons with chronic mental illness. *Occup Ther Ment Health* 16:15–32.
- Pilat MA, McFarland A, Snelgrove A, Collins K, Waliczek TM, Zajicek J. 2012. The effect of tree cover and vegetation on incidence of childhood asthma in metropolitan statistical areas of Texas. *HortTechnol* 22:631–637.
- Pincetl S. 2010. From the sanitary city to the sustainable city: challenges to institutionalising biogenic (nature's services) infrastructure. *Local Environ* 15:43–58.
- Poe MR, McLain RJ, Emery M, Hurley PT. 2013. Urban forest justice and the rights to wild foods, medicines, and materials in the city. *Hum Ecol* 41:409–422.
- Potwarka LR, Kaczynski AT, Flack AL. 2008. Places to play: association of park space and facilities with healthy weight status among children. *J Community Health* 33:344–350.
- Professional Landcare Network. 2014. *Love Your Landscape.com: Your Landscape, Our Passion*. Available: <http://www.loveyourlandscape.com> [accessed 29 December 2014].
- Reis S, Morris G, Fleming LE, Beck S, Taylor T, White M, et al. 2013. Integrating health and environmental impact analysis. *Public Health*; doi:10.1016/j.puhe.2013.07.006 [Online 4 October 2013].
- Rice JS, Remy LL. 1998. Impact of horticultural therapy on psychosocial functioning among urban jail inmates. *J Offender Rehabil* 26:169–191.
- Rizzo MJ. 1979. The effect of crime on residential rents and property values. *Am Econ* 23:16–21.
- Rounsevell MDA, Dawson TP, Harrison PA. 2010. A conceptual framework to assess the effects of environmental change on ecosystem services. *Biodivers Conserv* 19:2823–2842.
- Sander HA, Haight RG. 2012. Estimating the economic value of cultural ecosystem services in an urbanizing area using hedonic pricing. *J Environ Manage* 113:194–205.
- Sander H, Polasky S, Haight RG. 2010. The value of urban tree cover: a hedonic property price model in Ramsey and Dakota Counties, Minnesota, USA. *Ecol Econ* 69:1646–1656.
- Schipperijn J, Bentsen P, Troelsen J, Toftager M, Stigsdotter UK. 2013. Associations between physical activity and characteristics of urban green space. *Urban For Urban Gree* 12:109–116.
- Schrier AV, Bronfin J, Harrison-Cox J. 2013. *What is Your Planet Worth? A Handbook for Understanding Natural Capital*. Tacoma, WA: Earth Economics. Available: <http://www.earthconomics.org/FileLibrary/file/EE%20Handout%20Final.pdf> [accessed 27 March 2015].
- Seattle ReLeaf. 2013. *Finding the Magic of Trees: Connecting Seattle Residents to the Urban Forest*. Seattle, WA: City of Seattle.
- Sherman SA, Varni JW, Ulrich RS, Malcarne VL. 2005. Post-occupancy evaluation of healing gardens in a pediatric cancer center. *Landsc Urban Plan* 73:167–183.
- Shibata S, Suzuki N. 2002. Effects of the foliage plant on task performance and mood. *J Environ Psychol* 22:265–272.
- Soares AL, Rego FC, McPherson EG, Simpson JR, Pepper PJ, Xiao Q. 2011. Benefits and costs of street trees in Lisbon, Portugal. *Urban For Urban Gree* 10:69–78.
- Sugiyama T, Francis J, Middleton NJ, Owen N, Giles-Corti B. 2010. Associations between recreational walking and attractiveness, size, and proximity of neighborhood open spaces. *Am J Public Health* 100:1752–1757.
- Sukhdev P, Wittmer H, Miller D. 2014. The economics of ecosystems and biodiversity (TEEB): challenges and responses. In: *Nature in the Balance: The Economics of Biodiversity* (Helm D, Hepburn C, eds). Oxford, UK: Oxford University Press, 135–152.
- Takano T, Nakamura K, Watanabe M. 2002. Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces. *J Epidemiol Community Health* 56:913–918.
- Takebayashi H, Moriyama M. 2007. Surface heat budget on green roof and high reflection roof for mitigation of urban heat island. *Build Environ* 42:2971–2979.
- Taylor AF, Kuo FE. 2009. Children with attention deficits concentrate better after walk in the park. *J Atten Disord* 12:402–409.
- Taylor AF, Kuo FE. 2011. Could exposure to everyday green spaces help treat ADHD? Evidence from children's play settings. *Appl Psychol Health Well Being* 3:281–303.
- Taylor AF, Kuo FE, Sullivan WC. 2001. Coping with ADD: the surprising connection to green play settings. *Environ Behav* 33:54–77.
- Tennessen CM, Cimprich B. 1995. Views to nature: effects on attention. *J Environ Psychol* 15:77–85.
- Thorsnes P. 2002. The value of a suburban forest preserve: estimates from sales of vacant residential building lots. *Land Econ* 78:426–441.
- Tidball K, Krasny ME, eds. 2014. *Greening in the Red Zone: Disaster, Resilience and Community Greening*. New York: Springer.
- Tietenberg T, Lewis L. 2011. *Environmental and Natural Resource Economics*. 9th ed. Upper Saddle River, NJ: Prentice Hall.
- Troy A, Grove JM. 2008. Property values, parks, and crime: a hedonic analysis in Baltimore, MD. *Landsc Urban Plan* 87:233–245.
- Troy A, Grove JM, O'Neil-Dunne J. 2012. The relationship between tree canopy and crime rates across an urban-rural gradient in the greater Baltimore region. *Landsc Urban Plan* 106:262–270.
- Trust for Public Land. 2013. *Center for City Park Excellence Bibliography. The Economic Benefits of Parks*. Available: <http://www.tpl.org/center-city-park-excellence-bibliography> [accessed 29 December 2014].
- Tse M, Ng JKF, Chung JWF, Wong TKS. 2002. The effect of visual stimuli on pain threshold and tolerance. *J Clin Nurs* 11:462–469.
- Tsunetsugu Y, Park BJ, Miyazaki Y. 2010. Trends in research related to "Shinrin-yoku" (taking in the forest atmosphere or forest bathing) in Japan. *Environ Health Prev Med* 15:27–37.
- Ulrich RS. 1984. View through a window may influence recovery from surgery. *Science* 224:420–421.
- Ulrich RS. 1999. Effects of gardens on health outcomes: theory and research. In: *Healing Gardens: Therapeutic Benefits and Design Recommendations* (Cooper Marcus C, Barnes M, eds). New York: John Wiley & Sons Inc., 27–86.
- Ulrich RS, Simons RF, Losito BD, Fiorito E, Miles MA, Zelson M. 1991. Stress recovery during exposure to natural and urban environments. *J Environ Psychol* 11:201–230.
- United Nations Population Fund. 2007. *State of the World's Population 2007: Unleashing the Potential of Urban Growth*. Available: http://www.unfpa.org/sites/default/files/pub-pdf/695_filename_sowp2007_eng.pdf [accessed 27 March 2015].
- University of Washington. 2014. *Green Cities: Good Health*. Available: <http://www.greenhealth.washington.edu> [accessed 29 December 2014].
- U.S. EPA (U.S. Environmental Protection Agency). 2013. *Case Studies Analyzing the Economic Benefits of Low Impact Development and Green Infrastructure Programs*. Report EPA 841-R-13-004. Washington DC: U.S. EPA. Available: http://water.epa.gov/polwaste/green/upload/lid-gi-programs_report_8-6-13_combined.pdf [accessed 29 December 2014].
- Varni JW, Katz E. 1997. Stress, social support, and negative affectivity in children with newly diagnosed cancer: a prospective transactional analysis. *Psychooncology* 6:267–278.
- Voicu I, Been V. 2008. The effect of community gardens on neighboring property values. *Real Estate Econ* 36:241–283.
- Walch JM, Rabin BS, Day R, Williams JN, Choi K,

- Kang JD. 2005. The effect of sunlight on postoperative analgesic medication use: a prospective study of patients undergoing spinal surgery. *Psychosom Med* 67:156–163.
- Walker RE, Keane CR, Burke JG. 2010. Disparities and access to healthy food in the United States: a review of food deserts literature. *Health Place* 16:876–884.
- White MP, Alcock I, Wheeler BW, Depledge MH. 2013. Would you be happier living in a greener urban area? A fixed-effects analysis of panel data. *Psychol Sci* 24:920–928.
- Willis K, Crabtree B. 2011. Measuring health benefits of green space in economic terms. In: *Forests, Trees and Human Health* (Nilsson K, Sangster M, Gallis C, Hartig T, de Vries S, Seeland K, et al., eds). New York:Springer, 375–402.
- Wolf KL. 2008. Metro nature: its functions, benefits, and values. In: *Growing Greener Cities: Urban Sustainability in the Twenty-First Century* (Birch EL, Wachter SM, eds). Philadelphia:University of Pennsylvania Press, 294–315.
- Wolf KL. 2012. The changing importance of ecosystem services across the landscape gradient. In: *Urban-Rural Interfaces: Linking People and Nature* (Laband DN, Lockaby BG, Zipperer W, eds). Madison, WI:American Society of Agronomy, 127–146.
- Wolf KL. 2014. City trees and consumer response in retail business districts. In: *Handbook of Research on Retailer-Consumer Relationship Development* (Musso F, Druica E, eds). Hershey, PA:IGI Global, 152–172.
- Wolfe MK, Mennis J. 2012. Does vegetation encourage or suppress urban crime? evidence from Philadelphia, PA. *Landsc Urban Plan* 108:112–122.
- Zandbergen PA. 2009. Methodological issues in determining the relationship between street trees and asthma prevalence [Letter]. *J Epidemiol Community Health* 63:174–175.
-