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Economic values of metro nature health benefits: A life course approach

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ABSTRACT

The presence of metro nature enables daily environmental interactions, and a substantial body of evidence now demonstrates that nature contact generates extensive psychosocial, cognitive, and physical health and well-being benefits. Estimates of the economic values of such benefits have lagged similar valuation efforts for environmental services (such as improved air and water quality). In this article, using a life course approach, we estimate the potential annual value of six metro nature benefits, and cautiously extrapolate to a national scale, based on best available data and research. This is done by applying established economic values associated with epidemiology and public health to metro nature benefits estimates reported in prior peer-reviewed literature. The six situations of benefits valuation potential focused on: birth weight, attention deficit hyperactivity disorder (ADHD), school performance, crime, cardiovascular disease, and Alzheimer's disease. This benefits set demonstrates the importance of nature contact in urban areas over the course of the human lifespan. We estimate that the potential cost savings, avoided costs, and increased income range between $2.7 and $6.8 billion annually (2012 USD). Yet these values represent only a subset of benefits described in the current literature concerning urban nature experiences and health and well-being outcomes, pointing to the need for increased research concerning further valuations. We also point out challenges encountered in developing these estimates and limitations of their use. There is an urgent need to improve, expand, and integrate research methods and valuation strategies that link urban natural resources, public health, and economics. The resulting contributions to policy and programs can greatly improve urban quality of life.

1. Introduction

Environmental health disciplines have traditionally focused on recognition, impacts, and control of chemical and toxic exposure. Negative externalities associated with human contact with pesticides and herbicides, solvents, or pollutants situated in the environment have long been a major public health and societal concern. More recently environmental health practices have been expanded to include nature exposure as a contributor to human well-being and positive public health, in addition to concerns of risk reduction (Frumkin, 2005). A substantial body of evidence now demonstrates that equitably distributed, well-managed metro nature elements can be sources of environmental interactions that generate extensive physiological, social, and mental wellness benefits (Keniger et al., 2013; Russell et al., 2013; Hartig et al., 2014).

The term 'metro nature' is a broadly inclusive term which refers to collective opportunities for human nature experiences that promote wellness and improve urban livability (Wolf, 2008; Wolf and Robbins, 2015). It includes endemic ecosystems, such as remnant urban forest parcels, greenbelts, conserved open spaces, and riparian corridors that may be patch or relic expressions of native ecological associations. It also includes culturally constructed nature such as parks, streetscapes, community gardens, pocket parks, and recreational paths, as well as structural elements integrated within any built form to serve specific functions or supplement utilities, such as green roofs, green walls, or green infrastructure facilities.

Acknowledging potential contributions of metro nature for human health and wellness has important economic implications. The U.S. National Health Expenditure tally for 2012 was $2.9 trillion, representing 17.9% of the United States (U.S.) gross domestic product (World Bank, 2014), and health spending is projected to grow at an average rate of 5.7% from 2013 to 2023 (CMS, 2014). Considering both rapidly increasing costs and diminished quality of life associated with illness, there is an expanding interest in disease

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prevention and health promotion practices (Fielding et al., 2013; Office of Disease Prevention and Health Promotion, 2014).

Community health strategies are becoming more common (CDCP, 2009), in addition to individual health care, in addressing situations and contexts that can influence population health across a geographic area, such as a neighborhood or county (Kindig et al., 2008; Dannenberg et al., 2011). Also, disease prevention and health promotion initiatives must address human beings at all stages of the life cycle, as the implications of disease can extend beyond the time of any single diagnosis and treatment (Koplan and Fleming, 2000). Life course is defined here as a sequence of age categories that humans are normally expected to pass through as they progress from birth to death. Included in the culturally defined conceptions of the life course are estimates of how long they are expected to live and what constitutes "premature" or "untimely" death (Mayer, 2009). This paper uses the human life course (also referred to as life cycle) as an organizing framework, as it reflects increased public health messaging about the necessity for lifelong health support practices, rather than access to medical services only in times of illness.

The purpose of this overview and study is to estimate and present economic valuations concerning human health and wellness benefits associated with human experiences within the context of metro nature. To date, economic estimates of urban ecosystem services have largely centered on those described by the Millennium Ecosystem Assessment (MEA, 2005) as supporting and provisioning services. Such environmental benefits include surface and stormwater quantities and quality, air pollutant abatement, and microclimate amelioration (Chen and Jim, 2008). Research on psychosocial and public health benefits derived from metro nature have remained largely on the periphery of economic valuation discussions and assessments (Bratman et al., 2012; Smith et al., 2013). Modeling of benefits has led to economic valuations of environmental services (e.g., the USDA Forest Service i-Tree software suite) and provided a justification for local urban forest planning and investment (Hilde and Paterson, 2014); evidence of human health and wellness has only recently been included (Nowak et al., 2014). An expanded valuation effort offers additional opportunities to inform planning and management of metro nature and point to directions for future research.

This paper describes the culmination of an extended process of literature screening and assessment for valuation feasibility. Despite a sizeable and rapidly expanding evidence base concerning metro nature and associated human health and well-being (i.e., cultural ecosystem services), there is limited peer-reviewed literature on economic values associated with human health benefits. Considering trends in preventive health efforts and illness costs, a framework of 'cradle to grave,' or a life course perspective, of economic consequences, was used. Valuations were achieved using straightforward, traditional methods applied to benefit estimates derived from prior peer-reviewed literature. A range of potential economic impacts associated with life-long exposure to nearby nature in urban settings was explored, and demonstrates the need for further valuation studies. We acknowledge that this initial overview is schematic in character, but it initiates another public engagement strategy about human health and wellness benefits that can be an important contribution to national, and ultimately regional and local level commitments to metro nature planning, implementation, management, and quality of life issues.

2. Methods

2.1. Urban greening benefits and human life course

Life course has become a prominent framework for conceptualizing health (Fine and Kotelchuck, 2010), and scholars and practitioners are exploring its application to disease prevention and wellness (Halfon and Hochstein, 2002). Life course theory (LCT) offers a rich and layered understanding of how health develops over a lifetime and across generations (Hutchison, 2010). Individuals have different challenges, vulnerabilities, and strengths associated with general phases of human development. Availability of nearby nature in urban settings has now been scientifically linked to human benefits continually expressed in the human life cycle (Hartig et al., 2011). While LCT emerged to better understand and address developmental trajectories and disease incidence over lifetimes and across generations, it also facilitates a better understanding of patterns of health and disease disparities, and contributing factors of optimal human health (EU, 2014).

Naturalists, recreationists, and gardeners across the centuries have noted the restorative qualities of parks, gardens, and open spaces for human beings of all ages. Many human health services and benefits are provided by small-scale nature elements in close proximity to the everyday places of neighborhoods and communities. Evidence largely confirms such observations, and indicates fundamental emotional, cognitive, and physiological responses (Hartig et al., 2014). The evidence corpus spans several decades and includes contributions from numerous and diverse scholarly disciplines (e.g., psychology, anthropology, sociology) and applied professions (e.g., urban forestry, urban planning, epidemiology, education) (Wolf, 2012). The pace of research has rapidly increased in the past two decades (Hartig et al., 2014), perhaps corresponding with recent, accelerated urbanization and environmental degradation of the planet, and greater interest in disease prevention. Across this literature, estimations of potential economic values provided by urban ecosystem services have been limited (Bratman et al., 2012). In particular, estimates of the economic values of nature-based public health benefits have lagged valuation efforts for environmental services.

2.2. Study screening

We applied economic valuations to information secured from published studies, selected using a multi-step, iterative screening process. Reviews of current literature on the relationship between urban greening and human health were varied in purpose and content (Hartig et al., 2014; Wolf and Robbins, 2015). An ongoing, narrative literature review preceded this project and provided a literature database for screening. The Green Cities: Good Health website, is a science delivery project representing a collection of more than 3,000 peer-reviewed publications thematically sorted into 13 benefits topics (University of Washington, 2015). Articles have been collected and collated using keyword searches (e.g., Google Scholar, Web of Science, PubMed), review of tables of contents of key journals, and 'snowballing' from citations within collected articles (Konijnendijk et al., 2013).

A systematic and iterative screening protocol was developed jointly by the four authors (having backgrounds in natural resource, environmental psychology, and economics research). Our team first accessed the literature database to scope valuation potential. Articles were screened, selected, evaluated, and culled based on the following criteria: (1) reporting on an original scientific study, (2) clearly describing specified human contact(s) with nature combined with specified markers of health outcomes, (3) reporting on significant effects relevant for a distinct human population, and (4) representing studies with a range of metro nature responses across the human life cycle. In this way we only considered the best evidence sources and studies of appropriate scientific rigor. We used a standardized data extraction matrix to record the screening process and ensure a systematic review and data-retrieval within our team and across the candidate study benefits. Periodic consultations

among all researchers regarding whether to include a study or not generated a final list by consensus.

2.3. Evidence to economic valuation

Our initial assessment of the peer-reviewed literature yielded 15 health and well-being outcomes likely to be associated with economic benefits. We then conducted schematic, preliminary economic interpretations of the data. Valuations opportunities included human population effects, the scale of study finding, factor income, avoided cost, burden of illness, and cost-effectiveness analysis. Initial interest in benefits calculation at the municipal scale was put aside due to the paucity of local data, resulting in extrapolations using national data (consistent with Nowak et al., 2014).

After extended screening and preliminary valuation exercises we validated and selected six human life course situations: birth weight, ADHD, secondary school performance, crime, cardiovascular disease, and Alzheimer's disease. While not a complete representation of conditions or diagnoses that may occur within the continuum of a human life, the list addresses fairly common events or health conditions experienced by human populations in cities within industrialized nations. The results section presents each benefit situation and evidence of nature-based enhancements or abatement of negative conditions.

The selected benefits then underwent a more detailed analysis to further validate our situational choices, using best available studies and economic data. Valuation foundations were derived from national data (such as the Centers for Disease Control and Prevention [CDC]), state or regional data, or from special reports prepared by agencies or non-profit organizations. Each benefit was described in terms of potential cost savings or costs avoided, or other expressions of value. Outcomes for specific studies supporting each valuation were adapted to enable the derivation of reasonable estimations. Sources and calculations for value estimates are presented as results. We also present limitations because of the nascent nature of much of the source benefits research.

3. Results

The concept of life course describes a temporal progression of age categories with associated contexts and influences. The metro nature situations and associated responses presented are a subset of contexts and conditions that affect health of humans in various age categories. While there are certainly additional nature-based health influences, we present evidence-based examples from the most robust and generalizable prior research.

3.1. Birth weight

Birth weight is a widely used indicator of newborn health and, in some cases, a predictor of long-term childhood health and development (Paneth, 1995), with probable implications for adult disease incidence (Black et al., 2007; Johnson and Schoeni, 2011). Since babies born at low birth weight (LBW) (<2500 g) often require additional care, differences in birth weights are also associated with short- and long-term health care costs. Another metric of newborn health is relative size for gestational age. Small for gestational age (SGA) includes babies weighing below the 10th percentile. In 2000, one study on births estimated that in the U.S., 9% of Caucasian infants and 16% of African American infants were considered as SGA (Ananth et al., 2004).

Recent studies, though limited in number by location, have shown an association between greater tree canopy, proximity to open spaces, and reductions in LBW or SGA babies. Donovan et al. (2011) examined birth outcomes of singleton newborns in Portland, Oregon, U.S. and found an association between greater tree canopy and reduced risk of being SGA. Although they did not identify a causal mechanism, they found that a 10% increase in tree canopy within 50 meters (m) of the mother's home was associated with a reduction in the risk of SGA babies by 1.42 in 1000. Dadvand et al. (2012) conducted a similar study in Spain, using birth weight and proximity to green space and greenness, and found that an increase in vegetation coverage within 500 m was associated with higher birth weight. Similar results were found by Markevych et al. (2014) in a study conducted in Munich, Germany; Laurent et al. (2013) in Southern California, U.S.; and Hystad et al. (2014) in Vancouver, Canada.

Several studies estimated incremental costs associated with additional care needed for infants born in the LBW or SGA categories. Almond et al. (2005) estimated costs for U.S.-born babies weighing less than 2100 g at birth; for each loss of 400 g there was an associated additional care cost of $13,333 in the first year (2012 USD). They also estimated an increment of $133,333 for first-year care for babies born at very LBW (<1500 g). Russell et al. (2007) analyzed U.S. data on health care costs incurred within the first year of life for pre-term and LBW infants. Their estimates for additional care in the first-year of life ranged from $9,850 for SGA babies to $19,800 (2012 USD) for LBW babies.

To estimate potential savings in annual incremental hospital charges across the U.S., the Donovan et al. (2011) results were combined with cost estimates from Russell et al. (2007). Donovan et al. used data for one city; for illustrative purposes, we extrapolated this to the U.S. population. In 2010, the CDC estimated that nearly 3.7 million babies were born in the U.S. to Caucasian and African American mothers (Martin et al., 2012). Applying the Ananth et al. (2004) estimates for SGA percentages translates to approximately 378,000 babies born in the SGA category every year in the U.S. Using the Donovan et al. (2011) estimate on potential reductions implies the risk of SGA conditions could be reduced for 537 babies born in this category annually, translating to a potential cost reduction of $5.3 million (2012 USD) in the first year of life care. Estimates of birth weight impacts were not extended due to data limitations on the explicit effects of green elements and newborn birth weight, and limitations of extrapolating to later life stages. However, evidence in this area has grown significantly in the last few years and new evidence could result in more robust cost savings estimates.

3.2. Attention deficit hyperactivity disorder (ADHD)

In 2011, there were 5.24 million children ages 3–17 in the U.S. diagnosed with ADHD (Bloom et al., 2012). Studies have indicated that interactions with nature or green spaces can lead to significant reductions in ADHD symptoms (Faber Taylor et al., 2001; Faber Taylor and Kuo, 2009, 2011). Faber Taylor et al. (2001) found that Midwestern U.S. children who spent time in greener play areas had less severe ADHD symptoms. Faber Taylor and Kuo (2011) also found that children across the U.S. who routinely played (i.e., on a daily or near daily basis) in familiar green settings had milder symptoms than children who played in built outdoor or indoor settings. Faber Taylor and Kuo (2009) found that the effect of a dose of green (e.g., a 20 min walk in a city park) was substantial and roughly equivalent to the peak effect of an extended release stimulant medication methylphenidate, the most common ADHD medication. This would indicate the potential to replace medication entirely with a "dose of green" for some, and at least in part for others, depending on individual medication dosages. In the Netherlands (van den Berg and van den Berg, 2010) it was also concluded that the natural environment can reduce ADHD symptoms.

According to Visser et al. (2013), in the U.S. during the period 2007–2008, 66.3% of children with ADHD were taking medication

to treat this disorder. Applying this same percentage to the Bloom et al. (2012) estimate of the number of children diagnosed with ADHD in the U.S., an estimated 3.47 million children took medication to treat ADHD symptoms. Using a cost of illness framework, Pelham et al. (2007) estimated an annual cost of $14,576 per individual (2012 USD) in children and adolescents for ADHD treatment-related and other health care costs. Medication costs, depending on the drug type, dosage, and strength, ranged from $15 to $475 per month (2012 USD) (Consumer Reports, 2013). The monthly average for all medications listed was $184, including generic and brand-name medications at $108 and $232, respectively.

Based on the above studies, assumptions were made that nature exposure can be an alternative treatment for children suffering from ADHD and can be used in combination with – or as a substitution for – current medications. Assuming children who receive nature as part of their ADHD treatment could reduce medication amounts needed to treat their symptoms, estimated annual cost savings can be calculated. Findings in Faber Taylor and Kuo (2009) implied that for some children, up to 100% of their medication might be replaced with a "dose of green." Using the average monthly expenditures across all ADHD medications, based on a range of 5–25% medication replacement possibilities, we calculated a potential cost savings between $383.5 million (a 5% reduction) and $1.9 billion (a 25% reduction) (2012 USD).

Limitations of Faber Taylor and Kuo (2009) were its sole focus on a 20 min walk, testing of "results" immediately after the activity, and a lack of description on the length of effects. In general, studies have not indicated attributes or amount of green space that children need, frequency of exposure, nor length of time of exposure needed to alleviate or reduce ADHD symptoms in children. Another limitation was that this and other studies have not demonstrated that nature is a 100% effective alternative to current medications used to treat ADHD symptoms on a long-term basis. More detailed data is needed to derive formal prescriptions for nature therapy, and derive economic consequences. Savings could be significantly higher depending on reductions in medications used, and other medical costs associated with ADHD among U.S. children. Economic valuation may also include secondary benefits of ADHD reduction, such as adverse social effects on the individual due to disruption of personal interactions and work or school productivity.

3.3. Secondary school performance

To date, only a few studies have linked exposure to green elements with improvements in student performance and capacity to direct attention. Tennessen and Cimprich (1995) evaluated residents of U.S. college dormitories to test effects of natural and built views on attention restoration; natural views were associated with improved performance using attention indicators. Matsuoka's (2010), study of public high schools across several counties in Michigan, found that views from cafeterias as well as classroom windows with greater quantities of trees and shrub cover were positively associated with elevated standardized test scores, graduation rates, and percentages of students planning to attend a four-year college, as well as fewer occurrences of criminal behavior. Shibata and Suzuki (2001) examined interactions between indoor plants and undergraduate college student performance in Japan, finding that the presence of indoor plants positively affected task performance.

We applied the Matsuoka (2010) results to estimate potential economic values associated with "green" design. High school dropouts in the U.S. earn two-thirds less than their peers who finish high school (OECD, 2013). According the U.S. Census Bureau (2012), this equates to a difference of $11,000 in average annual income (2012 USD). Matsuoka's results on graduation rates show that, holding all other factors constant, for a one unit increase in quality of views of natural spaces from school cafeterias, there is an associated 2.9% increase in high school graduation rates. In 2012, for Michigan alone (MDE, 2013), this would imply a potential increase of approximately 1852 high school graduates. Applying this number to differences in average annual income, there would be an associated total increase of $20.4 million (2012 USD) per year. If extrapolated to the entire U.S., it would imply 114,813 additional high school graduates (USDE, 2013) per year, and an associated increase of almost $1.3 billion (2012 USD) in average total annual income for the cohort. This is a conservative estimate, as all income has secondary impacts on the economy, which were not included here.

The estimate on secondary school performance was limited primarily in terms of the strength of the study's association of views of green and school metrics. Matsuoka's study included three academic achievement measures, one of which was self-reported (plans to attend college). Measures based on official records, graduation rates, and state merit awards showed strong results in terms of an association between improved performance and access to green views. It should be noted that the measure of views was classified in categorical terms, thereby making it difficult to calculate student performance outcomes in relationship to a distinct unit of landscape change. Although research in this area is limited at this time, it clearly warrants further exploration.

3.4. Crime

As human beings age they set up households, and personal safety and security are important conditions for quality of life and community wellness. Several studies throughout the U.S. have shown a relationship between urban greening in a given area and levels of criminal activity. Kuo and Sullivan (2001) found that public housing buildings in Chicago, Illinois, U.S. having greener surroundings had fewer reported property and violent crimes. Using data from 2007 to 2010, Troy et al. (2012) found that a 10% increase in tree cover was associated with an 11.8% reduction in robbery, burglary, theft, and shootings in Baltimore County, Maryland, U.S. Branas et al. (2011) looked at the effect of greening vacant lots throughout Philadelphia, Pennsylvania, U.S. and found significant reductions between 1999 and 2008 across the city for assaults, gun robberies, vandalism, and criminal mischief. Wolfe and Mennis (2012) indicated that the abundance of vegetation in Philadelphia had a significant relationship with lower rates of assault, robbery, and burglary, although not theft. Donovan and Prestemon (2012) found that in Portland, Oregon, U.S. reductions in crimes (including property crimes and vandalism) around single-family homes were associated with specific tree sizes (e.g., larger trees correlated with reduced crime) along streets and on home lots.

Miller et al. (1996) and Heaton (2010) provided estimates for the per-event direct cost of different types of violent and non-violent crime across the U.S. For crimes included in studies considered here (i.e., robberies, assault, theft) the Miller et al. (1996) estimates ranged from $588 for theft to $24,000 for assault (2012 USD); Heaton (2010) estimates ranged from $2369 (2012 USD) for theft to $96,600 for assault. The Federal Bureau of Investigation (FBI) publishes yearly crime data by crime type and population group (FBI, 2014). We applied results from Troy et al. (2012) and Branas et al. (2011) that showed an association between greening areas, or increased vegetation, and reductions in crime of 8% in gun assaults. For comparability with Troy et al. (2012) and Branas et al. (2011), which focused on two relatively large U.S. cities (i.e., Baltimore and Philadelphia), we limited our estimates to statistics that reflected cities with populations greater than 500,000.

In 2012, there were a total of 1.8 million combined aggravated assault, robbery, burglary, and theft events in U.S. cities with

Table 1
Cost savings in millions of U.S. Dollars (2012) derived from crime reduction associated with greening in U.S. cities with a population over 500,000 in 2012.

	Robbery	Aggravated assault	Burglary	Theft	Totals
Total events (*n*)	122,069	177,397	335,220	1,168,860	1,803,546
Total costs ($)	976.6	4,257.5	745.5	1,642.0	7,621.6
Branas et al. (2011) estimated reduction ($)	–	340.6	–	–	340.6
Troy et al. (2012) estimated reduction ($)	115.2	502.4	88.0	193.8	899.4

populations greater than 500,000. Applying the Miller et al. (1996) values, in total, the impact of these crimes was valued at more than $7.6 billion (2012 USD). Applying the Branas et al. (2011) 8% reduction in gun assaults, we estimated $340.6 million (2012 USD) could potentially be saved in crime response costs (Table 1). Applying the Troy et al. (2012) 11.8% reduction across several crime types, an estimated $899.4 million (2012 USD) could be saved.

Limitations in the original studies on crime include the applicability of results across all sections of a city (not all sections showed similar reductions in crime rates). Additionally, there may be other contributing factors that were omitted. For instance, these studies do not address the issue of whether greening vacant lots results in the displacement, rather than elimination, of criminal activities, nor are mediating conditions reported, such as the condition of a city's economy, that could contribute to more or less crime.

3.5. Cardiovascular disease

Approaching middle- to late-age, human beings are more prone to certain chronic diseases. Cardiovascular disease is the primary cause of death in the U.S. and the United Kingdom (U.K.), being responsible for approximately 25% (CDCP, 2013) and 30% (Scarborough et al., 2011) of deaths per year, respectively. Studies examining the link between direct physical health and green space have utilized disparate measures of both health and green space, making comparability difficult. However, several studies in both locales have established a link between cardiovascular mortality and exposure to green space. Mitchell and Popham (2008) compared income and health with exposure to green space in the U.K., finding that health inequalities related to income deprivation in mortalities (from all causes and circulatory disease), was lower in populations living in the greenest areas (based on land use classification). Richardson and Mitchell (2010) looked at differences in cardiovascular and respiratory mortality by gender for U.K. adults, and found that males living near areas having greater than 25% green cover had a 5% lower risk of cardiovascular disease mortality. Donovan et al. (2013) compared the incidence of catastrophic tree loss due to infestations of emerald ash borer (EAB; *Agrilus planipennis*) to county-level public health records, finding a correlation between loss of trees and increased human mortality related to cardiovascular and respiratory illness. From 2002 to 2007, across the 15 state study area in the U.S., the estimated marginal effect of the EAB was an additional 6113 deaths related to illness of the lower respiratory system, and 15,080 cardiovascular-related deaths.

Cardiovascular disease, in the U.S. and U.K., is a major source of direct and indirect healthcare costs. In 2004, Luengo-Fernandez et al. (2006) estimated that the total cost of cardiovascular disease in the U.K. was $59.9 billion (2012 USD). As a subset of these costs, they estimated that mortality costs associated with lost productivity for adult males approached $7.0 billion (2012 USD). Applying these cost estimates to the Richardson and Mitchell (2010) study, a 5% reduction in risk of cardiovascular mortality would be associated with $348 million (2012 USD) in avoided annual mortality-associated costs in the U.K., based on 2004 total cost estimates. Based on similar socio-economic conditions of the two nations we posited that estimated avoided costs would be similar in the U.S., yielding a prorated U.S. population estimate of $1.2 billion (2012 USD) (OFNS, 2012; U.S Census Bureau, 2012).

Our estimates depended on the assumption that the distribution of areas with green cover could be increased to greater than 25% in and around homes and neighborhoods of male residents. Granted, no risk or lifestyle factors were accounted for in these estimates. Other methods to estimate economic values associated with cardiovascular disease mortality reduction, such as lowered direct medical costs (such as medications or hospitalizations), could not be incorporated in this valuation due to information constraints but would more than likely yield higher estimates of avoided costs.

3.6. Alzheimer's disease

Later adulthood may bring on an increased risk of declining mental capacity. In 2013, an estimated 5.2 million Americans were living with Alzheimer's disease, the 6th leading cause of death (Alzheimer's Association, 2013). Alzheimer's is but one of a number of cognitive impairments, collectively termed dementia, that primarily afflicts older individuals. Many late stage dementia patients exhibit agitated and aggressive behaviors, and were often treated with either psychotropic medications and/or physical restraints (Whall et al., 1997). Studies have demonstrated that dementia patients with access to therapeutic or outdoor gardens exhibit fewer disruptive or agitated behaviors (Ellis, 1995; Mather et al., 1997). Access to wander gardens (that is, outdoor confined spaces that enable activity without restraint, but prevent elopement) has also been associated with improvements in the ambulatory capacity of elderly patients (Murphy et al., 2010). At a dementia facility in Virginia, U.S. Detweiler et al. (2009) found that patients with access to a wander garden had about 30% fewer falls, accompanied by a reduction in fall severity. In addition, they found significant reductions in the amount of medications used (a 10.5% reduction overall, range of 3.4–22.2%) (Detweiler et al., 2009).

In the U.S., average annual cost per person for health care and long-term care services was $45,657 (2012 USD) for individuals with dementia, with prescription medication costs averaging $2787 (Alzheimer's Association, 2013). Another study, based on data from the 2010 U.S. National Health and Retirement Study, showed the average annual cost per person attributed to dementia ranging from $41,689 to $56,290 (2012 USD) depending on the method used to value informal care (Hurd et al., 2013).

Detweiler et al. (2009) showed that patients with access to a wander garden experienced a 10.5% reduction in the total amount of medications taken. We applied a range of 5–10% replacement of medication with horticultural therapy to derive potential cost savings. For the 5.2 million dementia patients in the U.S., we might expect an annual savings ranging from $725 million to $1.5 billion (2012 USD). Also noted by Detweiler et al. (2009), one harmful side effect of these medications is an increased risk of falls. Medical costs and other savings in health care costs associated with falls, not only for patients but also for medical facilities, would then likely be reduced. If these costs were accounted for, the use of horticulture therapy for dementia patients could potentially be substantially higher.

Limitations on Alzheimer's valuation estimates include the limited number of studies providing detailed information specifying reductions in medications and/or falls associated with being exposed to horticulture therapy or therapeutic gardens. Another limitation is the relatively small sample size in each study,

Table 2
Range of potential annual cost savings and increased income associated with human health and well-being benefits derived from metro nature elements (including urban open space and greening activities), in millions of U.S. Dollars (2012).

Benefit (geographic scope)	Minimum ($)	Maximum ($)
Newborn Health (U.S.)	5.3	5.3
Attention deficit hyperactivity disorder (U.S.)	383.5	1,917.7
Schools (U.S.)	20.4	1,262.9
Crime (U.S.)	340.6	899.4
Cardiovascular disease (U.K., U.S.)	1,220.0	1,220.0
Alzheimer's disease (U.S.)	724.6	1,449.2
Totals	2,694.4	6,754.5

and use of convenience sampling rather than probability sampling. More detailed research designs and associated data are needed to confirm assumptions in these estimations and generate more robust valuations. Savings derived from nature-based therapy and avoided costs could be significantly higher depending on reductions in medications used, and other medical costs associated with dementia patients.

4. Discussion

There is published evidence of substantial health concerns and consequences for urban residents at all stages of the human life course. A life course framing for nature-based valuations recognizes that: (1) health care costs are significant and increasing drastically; (2) holistic and preventive health care practices are gaining broader acceptance, including interest in the role of environmental influences; and (3) health promotion is not limited to treatment episodes, but is recognized as a continuum of conditions and early health situations that influence health conditions later in life.

Our incipient approach estimated values for a specific subset of all human health and well-being benefits, carefully selected and conservatively calculated, but significant nonetheless. Summing the valuation estimates, we found a potential annual range of $2.7 billion to $6.8 billion (2012 USD). If only health systems costs are included, total annual values could range from $2.3 billion to $4.6 billion (2012 USD) (Table 2). Although this is but a fraction of annual health industry spending (more than $2.9 trillion in the U.S. in 2012), it is still noteworthy, and there may be variable and higher impacts depending on the locale and the ripple effects in an economy. There may be additional economic value in health promotion if early onset interventions prevent later disease conditions (such as linkages between low birth weight and ADHD (Mick et al., 2002)).

Additional estimations that include all evidence-based benefits could generate greater public interest in metro nature as a health promotion mitigation and abatement investment in communities. Many studies evaluating costs of disease, crime, and other social issues call out the need for exploration and introduction of cost-effective prevention innovations. Although costs associated with expanding or improving urban green elements were not evaluated in our overview, our estimated values support a call out by Hartig et al. (2014) for further research linking metro nature and human health and well-being outcomes, and the range of associated economic values. As benefit monetization approaches are improved, costs of metro nature implementation and management should be appraised. More robust benefit-cost analyses would then be possible relative to treatment strategies or community interventions.

4.1. Valuation challenges

Despite the evidence linking health and environment, we found few peer-reviewed economic valuation estimates of such benefits. This, in part, explains why some studies incorporated in our analyses were outside the U.S. This study was a first-attempt at filling that gap. Using results from existing studies concerning sites of different scales and locations, we developed estimates of dollar values of human health and well-being impacts. Because some economic data were only available at national levels, and because we wanted to demonstrate the broader significance of values presented at a national scale, we made assumptions about the applicability of results. We recognized that this second-best approach was somewhat similar to benefits transfer approaches and as such has inherent limitations (Wilson and Hoehn, 2006; Plummer, 2009).

Since most source studies were not designed to include a valuation component, a number of challenges were encountered while developing these estimates. First, geographic scope varied greatly when integrating measures of urban natural resources (UNR) and public health/epidemiology (PHE). Generally, UNR spatial data is provided at the parcel scale or as vegetation units, while PHE data is recorded by administrative boundaries such as census blocks or by county. This led to significant challenges in establishing comparability between the spatial units of studies and associated economic elements.

A second challenge was the minimal comparability of outcome measures across studies, an observation supported by Hartig et al. (2014). For instance, there are now numerous studies on crime and vegetation. Across these studies outcome metrics varied substantially. In addition, the landscape unit of analysis varied, such as independent measures of tree canopy versus parks, or scales for degree of vegetation presence. Looking across multiple studies of a single benefit we occasionally found comparability of one aspect of a study that included numerous metrics. So there may have been comparability between vegetation characteristics or comparability between PHE outcomes, but not necessarily both. Furthermore, researchers rarely provided interpretations of their statistical coefficients, and consequently, interpretations of specific effects of health outcomes were made more difficult.

Few studies acknowledged potential confounding factors that may affect analysis results. As an example, when considering the role of green factors in crime reduction, there are policing and law enforcement, infrastructure, or socio-economic contingencies that were likely impacts. Few articles indicated consideration of such possibilities (beyond basic demographics) or reported whether such conditions were constant during the study period. Knowing about additional mitigating or mediating variables (Lachowycz and Jones, 2013) would make economic estimations more robust, and defensible if used as the basis to support local or state government policy or programs.

There were other limitations in our reliance on previous research which influenced the literature screening process. There was often little comparability between human populations studied, across geographic and cultural boundaries. Some articles failed altogether to specify the human population being studied. It was also evident that cities had different standards for vegetation implementation and management (both within and across nations), thus there was unstated variability of primary independent variables. Absence of such key information in research publications makes comparisons across studies difficult and potentially inaccurate.

4.2. Future needs and directions

There appeared to be different fundamental assumptions between the PHE and UNR fields concerning metro nature research. The prevailing focus of PHE was the potential risks, toxin exposure, or environmental decline, and this has shaped research questions and analysis approaches in the PHE field. When PHE investigators did study benefits, measures of association between simplistic expressions of nature – a dichotomous variable being whether

vegetation or a park is present or not – were correlated with more detailed health outcomes. UNR investigators, on the other hand, tended to detail vegetation and nature presence with more specificity (e.g., large versus small trees, vegetative attributes, park elements), but used *ad hoc* health measures that did not align with conventions of public health or epidemiology research.

We have several suggestions for moving forward and advancing research in this area. A new inter-disciplinary approach that combines public health, natural resources, and economics is called for. Within the health care industry, economic considerations are central when new strategies for disease prevention and health and wellness promotion are being examined. Currently, certain economic methods are shared between epidemiology and resource economics, providing the initial integration. Additional conceptual work is needed to develop a more productive nexus of public health, urban greening, and valuations. One opportunity would be to promote data consistency at state and federal levels for U.S. studies and advocate for similar consistencies in other nations. A federal agency that addresses either natural resources or public health could establish a science team or temporary center to review both domains of science and make recommendations (such as the National Academies of Science).

5. Conclusions

This overview and assessment was a preliminary demonstration of the range of nature-based economic valuations representing situations that span the entire human life course, from birth to old age. Some cities have begun to develop policies and programs in response to growing evidence of metro nature benefits. But such initiatives often face public challenges, such as other programmatic priorities (e.g., emergency services and housing), that force difficult funding decisions. Economic valuation is not a complete expression of benefits and costs, but it is a standard input for public dialog about community investments. Additional study is needed to develop more robust valuations, and support public programs dedicated to urban resources systems generating health and well-being benefits. Valuations might also encourage the health insurance industry to underwrite metro nature improvements and facilities, or convince corporations to engage in nature-based workplace or residential enhancements. Better valuation information might also motivate individuals to adopt more healthful lifestyles, and promote those behaviors with family, friends, and neighbors across the entire human life course. Our valuation assessments are a starting point for understanding economic consequences of metro nature investments, and for informing better policy, planning, and management of urban nearby nature.

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