Urban forests in the Anthropocene: The responsibility of urban forestry in meeting global sustainability challenges

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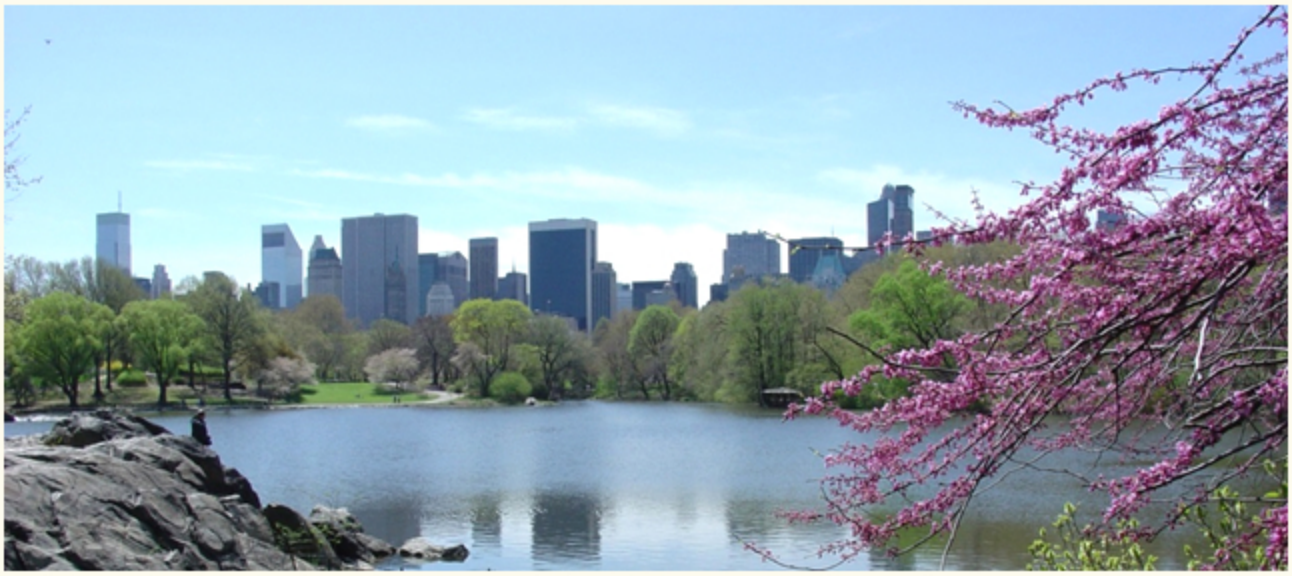

Zhu Ning
David J. Nowak
Gary Watson

International Society of Arboriculture

Urban Forest Sustainability

Zhu Hua Ning

Department of Urban Forestry and Natural Resources
College of Agricultural, Family, and Consumer Sciences
Southern University and A&M College System
Baton Rouge, Louisiana, U.S.

David J. Nowak

Northern Research Station
USDA Forest Service
Syracuse, New York, U.S.

Gary Watson

Morton Arboretum
Lisle, Illinois, U.S.

International Society of Arboriculture
Champaign, Illinois, U.S.

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Urban Forests in the Anthropocene: The Responsibility of Urban Forestry in Meeting Global Sustainability Challenges

Jessica M. Vogt*

Abstract

Scientists now acknowledge that our planet has entered the Anthropocene—a new geologic epoch in which humans are the drivers of rapidly changing global and local environmental conditions. The pressures of the Anthropocene threaten the future of humanity: extraction of increasingly limited natural resources; pollution of air and water; loss of biodiversity and ecosystem services; and rapidly increasing human populations. Moreover, climate change—increasing temperatures, greater rainfall variability, and extreme weather events—compounds all other pressures. The majority of these impacts will be felt by urban areas; 54% of people already live in cities, and by 2050, this number will be 66%. To make sure that future urban societies have the physical, human, social, and natural capital necessary to produce a reasonable quality-of-life despite the pressures of the Anthropocene, we need radical efforts to redesign our worldviews and activities to recognize the biophysical limitations of our planet. Urban forests and greenspace have the ability to mitigate some of the above pressures on urban societies. For instance, urban forests produce environmental benefits—*e.g.,* carbon sequestration, reduced air temperatures, stormwater management, air pollution reduction—and economic benefits—*e.g.,* decreased energy costs—that can lessen the impacts of climate change on cities. However, less quantified are the *social benefits* of urban forests and the potential of these benefits to contribute to sustainable cities in the Anthropocene. Social benefits from trees and greenspace accrue to individuals and communities, including improved human and social capital resulting from participation in greening activities. In this article, I discuss the pressures of the Anthropocene through the lens of sustainability science, and make a case for the responsibility of the urban forestry and urban greening community to contribute to the capacity of people and cities to respond to and prepare for the challenges of the Anthropocene.

Key words: anthropocene, urban forestry, sustainability.

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*Environmental Science and Studies Department, College of Science and Health, DePaul University, Chicago, Illinois, U.S., jessica.m.vogt@gmail.com.

Introduction

Humanity is facing challenges unprecedented in our past—extraction of increasingly limited natural resources; pollution of air and water; loss of biodiversity and ecosystem services; and rapidly increasing human populations (Steffen et al. 2015a). Moreover, climate change—increasing temperatures, greater rainfall variability, and extreme weather events—compounds all other pressures (IPCC 2014). The urgency of responding to these challenges is now paramount: each passing month is routinely declared the hottest on record (NOAA 2016), and scientists have recently declared that human impact on the planet is so significant as to have caused the Earth to enter an entirely new geologic epoch called the Anthropocene (*e.g.,* Steffen et al. 2015a; Waters et al. 2016; Brondizio et al. 2016).

Urban forests and greenspace have the ability to mitigate some of the above pressures on urban societies. In this article, I outline the pressures of the Anthropocene through the lens of sustainability science, and make a case for the responsibility of urban forestry and urban foresters to contribute to the capacity of urban communities to respond to and prepare for the challenges of the Anthropocene. I argue that the urban forestry and urban greening community has a responsibility to effect dialogue and action towards sustainability.

The Anthropocene

It took humans 4 million years to get to 1 billion people on the planet, yet in the 12 years from 1999 to 2011, the population grew from 6 to 7 billion (Steffen et al. 2015a). Primary energy use today is more than 30 times what it was in 1750. Water use has increased by a factor of six in the last century alone. Paper use today is 500% of use in 1961. Global gross domestic product (GDP) has increased by more than 140 times between 1750 and 2008. Tropical forest loss has accelerated dramatically, and tropical forest cover is now nearly 30% less than it was 400 years ago (Steffen et al. 2015a). A recent widely publicized paper in *Nature* estimated that nearly half of trees have been cut down since the dawn of human civilization (Crowther et al. 2015). As a result of humans burning fossil fuels and changing land use patterns, carbon dioxide (CO_2) in the atmosphere now far exceeds natural levels: as of December 2016, global mean monthly CO_2 levels were 404.5 ppm, as measured at Mauna Loa observatory (NOAA 2017). These levels are "unprecedented" on planet Earth in the last 800,000 years according to the Intergovernmental Panel on Climate Change (IPCC 2014). Along with CO_2 levels, temperatures have risen 0.85° C

(1.53° F) between 1880 and 2012 (*ibid.*), and are currently 0.5° C (0.9° F) warmer than the average from 1961-1991 (Steffen et al. 2015a).

These are just some of the statistics highlighted in a January 2015 article from scientists at the International Geosphere-Biosphere Program (IGBP) and Stockholm Resilience Institute (*ibid.*). Earth systems scientists now argue that humanity and planet Earth has entered a new geologic epoch—the *Anthropocene*, in which humans are the single, overwhelmingly dominant force on the planet (*ibid.*; first named in the literature by Crutzen [2002]; see Brondizio et al. [2016] for a recent bibliometric review of publications on the Anthropocene). The Anthropocene is geologically and biogeochemically distinct from the last ~11,700 years of the Holocene (Waters et al. 2015). It is characterized by dramatically increased and increasing human use of materials and natural resources and expulsion of wastes into the environment, starting with what these authors call The Great Acceleration of these activities beginning after World War II (Steffen et al. 2015a). Recently, geologists have verified that the Anthropocene is stratigraphically distinct from the Holocene. Soil and ice cores from the last several thousand years are distinctly different from recent layers in terms of plastics, nitrogen deposition, nuclear fallout, which signals human dominance on Earth's air, water, and land systems (Zalasiewicz et al. 2015; Waters et al. 2016). This evidence of change in ice cores starts at approximately 1950, the date that many sustainability scientists argue marks the beginning of the Anthropocene epoch (*e.g.,* Zalasiewicz et al. 2015; Steffen et al. 2015a; Waters et al. 2016; Brondizio et al. 2016).

Sustainability for cities in the Anthropocene

Given these challenges, scientists from the Stockholm Resilience Institute have defined a set of nine "planetary boundaries," or key Earth system limits that we must stay within in order to operate "safely" in the Anthropocene (Rockstrom et al. 2009; Steffen et al. 2015b). These authors call this a "safe operating space for humanity"—where (1) atmospheric CO_2 levels are below 350 ppm; (2) forest cover is maintained at 75% of natural levels (and 85% of tropical forests are intact); (3) species extinctions are closer to natural background rates than present rates; (4) nitrogen and phosphorous runoff into aquatic ecosystems is limited; (5) freshwater use is below natural regenerative capacities; (6) excessive ocean acidification is prevented; (7) atmospheric air pollution is below levels dangerous to human and ecosystem health; (8) chemical pollution and other anthropogenic novel entities that harm people and the environment are

managed; and (9) the depletion of stratospheric ozone is prevented (*ibid.*). Ultimately, the planetary boundaries aim to provide guidance and ensure that key Earth processes remain at levels that do not threaten ecological integrity and human persistence on the planet. Based on the planetary boundaries framework (Rockstrom et al. 2009), Oxfam fellow Kate Raworth (2012) proposed the addition of eleven key human needs called the "social foundations" to the mostly-environmental planetary boundaries. The social foundations are food, water, healthcare, education, energy, jobs, income, gender equality, social equity, resilience, and voice. This space in between the planetary boundaries and social foundations—where we are not exceeding any of the Earth systems biophysical limits, but we are providing for the needs of all people on the planet—forms a "safe *and just* space for humanity" (*emphasis added, ibid.*; Leach et al. 2013). The true challenge of the Anthropocene, then, is to meet the social foundations for people while remaining within the Earth's planetary boundaries. *This is sustainability in the Anthropocene.*

The sustainability challenge—meeting human needs for present and future generations without sacrificing ecological integrity—is amplified in cities. Eighty percent of people in industrialized nations and 54% of the global human population live in urban areas, a figure projected to rise to two-thirds by 2050 (UN Population Division 2014). The stressors of the Anthropocene—rising population, climate change, limited natural resources including water, increased incidence of pests and diseases, threats to ecosystem integrity and more—are predominantly experienced and caused by urban areas. Cities are responsible for an estimated 60-70% of the anthropogenic greenhouse gas emissions that are causing climate change (Kammen and Sunter 2016), produce 70% of global waste, and account for 70% of global economic activity (as measured by GDP) (UN Habitat III). Making sure cities are sustainable in the future will be crucial for ensuring community livability and sustainability for the nearly 4 billion current urban residents, not to mention the additional 2.5 billion city-dwellers that will be added by mid-century (UN Population Division 2014).

Urban Forestry in the Anthropocene

Urban forestry and urban greening could play a significant role in ameliorating the stressors of the Anthropocene. There are two primary pathways through which this might happen. First, urban forests and other types of vegetation and greenspace in cities (including street trees, parks, remnant forests, and other natural areas and green infrastructure, managed or unmanaged) produce environmental and economic benefits that can lessen the impacts of climate change on cities. The physical presence of urban forests can impact local climate through direct mitigation of greenhouse gases: Trees and vegetation photosynthesize, sequester and (for woody vegetation) store CO_2 (McPherson and Kendall 2014; but see also Pataki et al. [2005] re: the limitations of carbon storage capacity in urban soils and vegetation). Urban forests also help cities adapt to climate change: trees lower temperatures and moderate the urban heat island (Armson et al. 2012), help cities cope with extreme heat events (Stone et al. 2012), decrease energy consumption (Zhang et al. 2014), manage stormwater during rainfall events (Livesley et al. 2016), and reduce air pollution (Nowak et al. 2013, 2014; but see also Setälä et al. [2013]).

The second pathway through which urban forests might help cities cope with the Anthropocene is via the social benefits of urban forests and urban greening. Benefits such as improved social capital (Holtan et al. 2014), personal empowerment (Westphal 2003), civic engagement (Fisher et al. 2015), ties between neighbors (Kuo et al. 1998), and decreased incidences of certain types of crime (Wolfe and Mennis 2012) might arguably improve capacity of a community to deal with the challenges of the Anthropocene (*e.g.,* climate change: Adger 2003).

To make sure that current and future urban societies have the capacity necessary to produce a high quality of life despite the pressures of the Anthropocene, we need radical efforts to redesign our worldviews and activities in order to live within the biophysical limitations of our planet (O'Neill 2012; Kallis et al. 2012, 2014; Asara et al. 2015). As such, in this section, I argue that the urban forestry and urban greening community has a responsibility to effect dialogue and action towards sustainability. The remainder of this piece begins to answer two questions in this dialogue (Figure 1):

Question 1: How can urban greening generate the natural, built, human, and social capital to sustain individuals and communities?

Question 2: Can urban greening improve the capacity of individuals and communities to deal with the pressures of the Anthropocene?

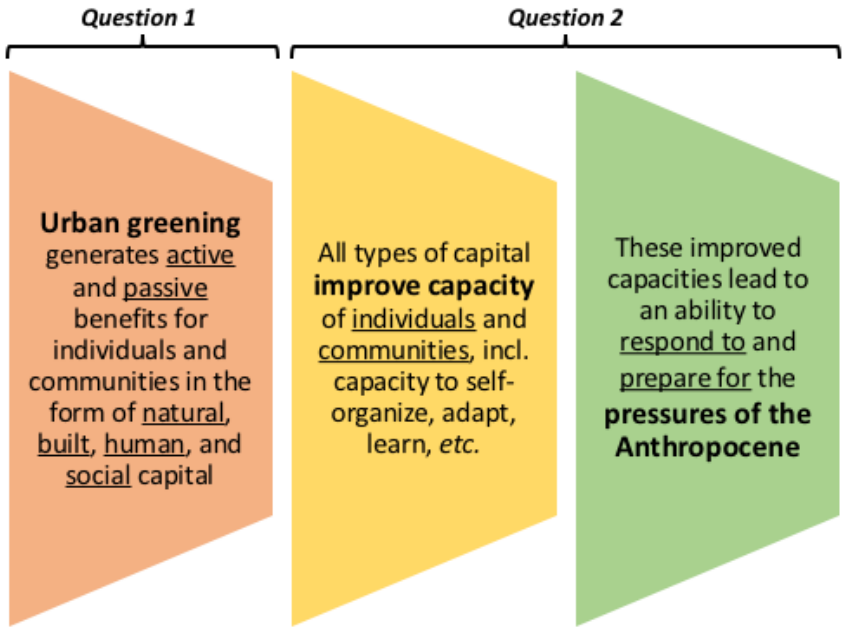

Figure 1. Theoretical linkages between urban greening, and the capacity of individual, organizations, and communities to respond to and prepare for the pressures of the Anthropocene.

How can urban greening generate the natural, built, human, and social capital to sustain individuals and communities?

Urban greening in the Holocene

Urban forestry and the related term urban greening include any efforts to manage green infrastructure or greenspace in cities and towns, including planting and caring for trees; landscaping medians, boulevards, or other common spaces; creating small pocket parks; community gardens (food or otherwise); installing and maintaining rain gardens; undertaking ecological restoration activities in semi-natural areas in and around cities; and any number of other activities relating to managing urban natural resources.

Although urban forestry is a term developed during the Anthropocene (attributed to a 1965 address by University of Toronto professor Erik Jorgensen), people have attended to urban nature ever since there have been permanent settlements (Gerhold 2007). Over the last 8,000 years of the Holocene during which humans have lived in relatively stable settlements (Gowdy and Krall 2013), there are examples of ancient civilizations, including the Egyptians in as early as 1400 B.C.E., planting rows of trees in gardens and along streets (Gerhold 2007). The systematic management of urban nature and trees, however, is a much more recent phenomenon. In the United States during the late-1800s wave of interest in environmental conservation, the first "tree warden" laws were passed by states in the Eastern U.S., allowing municipalities to take responsibility for the care of shade trees on public land and in the right-of-way (Ricard 2005). Frederick Law Olmsted and his contemporaries began designing large public parks about the same time (Central Park in New York City in 1857 [Gerhold 2007]; Boston's Emerald Necklace of greenspace corridors ringing the city in the 1870s [http://www.fredericklawolmsted.com /boston.html]) (Eisenman 2013). With the formation of the International Society of Arboriculture in 1975 (Gerhold 2007) and the explosion of research and practice of the 1970s and 1980s (Konijnendijk et al. 2006), management of trees became standard in many cities in North America.

The primary reason for managing trees and greenspace in cities (and the means of justifying expense of public tax dollars to do so) is the many benefits urban forests, trees, and vegetation provide to city residents. Through these benefits, urban greening contributes to building *capital* in the city. Capital, in economic literature, is often equated to wealth, in particular financial wealth and tangible assets. However, capital comes several main forms: *financial capital* (money, monetary assets, stocks, bonds, *etc.*), but also, *natural capital* (ecosystem services provided by communities of living organisms in the natural world, or from natural elements installed or restored by humans; see Costanza et al. [1997] for an early discussion of the valuation of the natural capital provided by the Earth's natural ecosystems); *built capital* (or physical capital assets, human constructed elements of the physical environment; complementary to natural capital [O'Neill 2012]); *human capital* (abilities and capacities of individual people, including education, health, skills, *etc.*; fostered by social capital [Coleman 1988]); and *social capital* (communities of connected individuals and groups and the relationships between them [Sampson et al. 1999; Sampson and Graif 2009; Collins et al. 2014];

collective efficacy or organizational capacity, neighborhood cohesion, competence, and sense of community, are all part of social capital [Lochner et al. 1999]).[1]

Urban forestry and urban greening activities (both research and practice) in the late Holocene (pre-1950) and early Anthropocene (1950-present) have mostly concentrated how trees generate built and natural capital in cities. Contributions of the urban forest to natural and built capital are perhaps the most concrete as these two types of capital are visible in our environments. The five most commonly valued[2] benefits of urban trees and vegetation—stormwater management, carbon sequestration and storage, air pollution removal,[3] energy savings, and property value increases (*e.g.,* McPherson et al. 2016)—are direct expressions of benefits resulting from the physical presence of the urban forest. These and other ecosystem services generated by the physical presence of trees in cities have been well-studied for the past couple decades (enabled largely by the use of the tree valuation software suite i-Tree [http://www.itreetools.org]; *e.g.,* McPherson et al. 2016). Because these environmental ecosystem services have been largely "mainstreamed" into urban forestry and urban greening discourse and practice (Silvera Seamens 2013; Young 2013), I will focus in the next section on the social benefits of urban greening, which have more interesting implications for engagement with sustainability in the Anthropocene.

The social benefits of urban greening as human and natural capital

The human capital and social capital benefits of the urban forest have been less well quantified and valued (Wolf et al. 2015), despite the increasing interest in these types of benefits, particularly over the past half-dozen years. Examples of active transdisciplinary research efforts (applied research, involving multiple disciplines as well as practitioners) that are examining the

[1] Some also add *cultural capital* to this list to refer to the wealth of knowledge, traditions, customs, *etc.*, gathered by experiences of individuals (Lewicka 2005). I consider this definition of cultural capital similar enough to human capital for the purposes of this paper.

[2] Here, "valued" means monetized, though monetization of benefits is by no means necessary to connecting the benefits of trees and greenspace to natural, built, human, and social capital. Indeed, "social capital" is frequently measured—see Lochner et al. (1999), Sampson et al. (1999), Sampson and Graif (2009), Collins et al. (2014)—but almost never monetized.

[3] But see the emerging debate around whether or not urban trees actually reduce *net* air pollution concentrations in all areas within a city, the varied impacts of trees on different types of air pollutants, and the need for much better data about this and other biophysical benefits provided by urban trees: Pataki et al. 2011; Setälä et al. 2013; Pataki et al. 2013.

social benefits of tree planting and urban greening activities include (but are not limited to) those in the following cities (select publications since 2010 listed in parentheses):

- Indianapolis, Indiana (Mincey and Vogt 2014; Vogt and Fischer 2014; Vogt et al. 2015; Watkins et al. 2016)
- Los Angeles, California (Pincetl et al. 2013)
- New York City, New York (Lu et al. 2010; Morani et al. 2011; Moskell and Allred 2013; Fisher et al. 2015)
- Philadelphia, Pennsylvania (Yang and Matthews 2010; Wolfe and Mennis 2012; Roman et al. 2015; Watkins et al. 2016)
- Portland, Oregon (Donovan and Butry 2011; Donovan and Mills 2014; Driscoll et al. 2015; Shandas 2015)

Social benefits research has also been conducted at the two U.S. National Science Foundation-supported urban Long-term Ecological Research (LTER) sites in Baltimore, Maryland (http://www.beslter.org) and Phoenix, Arizona (https://sustainability.asu.edu/caplter/).

Social benefits derived from urban greening can be classified by whether they accrue due to *passive* experience of or *active* engagement with urban green infrastructure, and by the level of society to which these benefits accrue (to *individuals*, to an *organization*, or the *community*) according to a typology developed by Westphal (2003). Table 1 contains select examples of social benefits observed in the literature in a modified version of the Westphal (2003) typology. Benefits from the physical presence of urban trees and greenspace are passively derived, since they result from humans passively experiencing trees in their city, and do not require direct interaction between people and the trees or vegetation producing benefits (Westphal 2003). Active involvement in urban greening activities—for example, when individuals physically participate in the act of planting or caring for trees or engage in urban gardening activities—results in different types of benefits to individuals or communities (*ibid.*). Both active and passive greening can arguably build all of the aforementioned types of capital (natural, built, human, and social), but I focus here on how a particular type of active greening—tree planting (by individual homeowners, volunteers in coordination with nonprofits or municipalities, *etc.*)—can build human and social capital.

Table 1. Examples of social benefits of urban greening (and select citations), according to a typology modified from Westphal (2003).

	Passive experience	Active involvement
Individuals	Personal health: Faster recovery from surgery *(Ulrich 1984)* and stress *(Ulrich et al. 1991)*; Improved health perception *(Kardan et al. 2015)*; Decreased attention deficit symptoms (*Faber-Taylor et al. 1991)* and body mass index *(Bell et al. 2008)* in children; Increased likelihood of walking *(Lachowycz and Jones 2014)*	Civic engagement capacity *(Fisher et al. 2015)*; Personal empowerment *(Westphal et al. 2003)*; Sense of satisfaction and ownership of yard/neighborhood *(Sommer et al. 1994a; Summit and McPherson 1998; Locke et al. 2015; Conway 2016)*
Communities (groups, organizations, neighborhoods, cities, *etc.*)	Increased retail sales for businesses *(Wolf 2005a, b)*; Public/community safety *(Wolfe and Mennis 2012)*	Organizational capacity/effectiveness *(Mincey and Vogt 2014; Roman et al. 2015);* Community capacity for collective action *(Mincey and Vogt 2014)*

Tree planting builds human capital

The earliest studies of the social benefits of urban tree planting were those of Sommer, Summit and colleagues in Bay Area California in the mid-1990s. Sommer et al. (1994a) surveyed residents in Fresno, California with experiences in tree planting: some residents had the city plant a tree in front of their house (a passive experience), while other residents participated in the tree planting activities, either independently (owners planted trees) or with a local nonprofit organization. Active experiences led to greater satisfaction with outcomes (tree location, staking, aesthetics) and yielded greater overall positive feelings about the neighborhood including higher ratings of "neighborhood friendliness" and "neighborhood attractiveness," and those residents who had collaborated with the nonprofit to plant trees reported the highest levels of satisfaction (Sommer et al. 1994a). A separate study by the same research group revealed very low satisfaction for trees planted by developers (Sommer et al. 1994b).

With respect to human capital, valuing and taking charge of the aesthetic appearance of one's yard has emerged as a motivating factor for tree planting in several studies. Summit and McPherson (1998) observed that aesthetics and shade dominated among criteria for planting trees, while convenience was the primary motivator of any tree care or maintenance actions

performed, for residents in Sacramento, California. Research nearly two decades and an entire continent away confirms these findings exactly: a study by Locke et al. (2015) of New Haven, Connecticut residents again found aesthetics to be the motivator for resident requests for a street tree to be planted near their home. And most recently, Conway (2016) found that residents in Mississauga, Ontario, Canada are taking ownership of their urban forest and are actively engaged in managing the trees in their yards, and that aesthetic appearance was the leading motivator of planting and removal decisions. This sense of satisfaction and ownership of one's yard and neighborhood is an important component of what environmental psychologists call a 'sense of place.' Sense of place (alternatively, place attachment) has been found to be positively related to civic activities (*e.g.,* participation in neighborhood activities, involvement with local nonprofits, political action) as well as to neighborhood ties (Lewicka 1999).

It is perhaps for this reason that civic engagement also has been found to be both a motivator and a result of involvement in tree planting. *Civic engagement* is the participation in discussion and/or addressing issues of general public concern, and may also be called civic activity (as in Lewicka 1999) or citizen participation. Examples of civic engagement include voting or participating in an election or other political action, joining a parent-teacher association or crime watch group, volunteering for a local community group, or discussing community health issues with a neighbor. Fisher et al. (2015) reported on the experiences of volunteers who planted trees in New York City with the MillionTreesNYC program organized by NYC Parks and a local nonprofit greening foundation. They found that volunteers in tree planting also were more engaged in other civic activities (but note that these findings were tightly entwined with the demographic characteristics of volunteers; *ibid.*).

Tree planting builds social capital

Nonprofit-led tree planting can also build social capital. Summit and Sommer (1998) examined the tree-planting programs of four northern California nonprofits that distributed trees at low or no cost and required that neighborhood residents participate in tree planting during an event at which the nonprofits instructed on how to properly plant and care for trees. In surveys of participants, they observed that planting not only improved individual capacity and efficacy (human capital), but also neighborhood cohesion: 45% reported giving or receiving help to or

from a neighbor during the planting event, while 53% of participants reported knowing their neighbors better after the planting (Summit and Sommer 1998).

On an organizational and community level, Mincey and Vogt (2014) found increased collective action capacity in neighborhoods that had participated in collaborative projects to plant and water trees in neighborhoods in Indianapolis, IN with a local nonprofit organization. Among participating neighborhoods, neighborhoods that watered trees together as a group actually engaged in more collective activities (such as a crime watch or neighborhood cleanup) after the tree planting than before, compared to neighborhoods where trees were watered by individuals acting alone (Mincey and Vogt 2014). Additionally, the nonprofit organization that coordinated these tree-planting activities was fostering neighborhood empowerment and capacity to self-organize by allowing neighborhoods to choose their own tree watering strategies (Mincey and Vogt 2014). Finally, the nonprofit was building their organizational capacity and social capital by (1) creating partnerships with neighborhood and community groups, local businesses, and the City of Indianapolis; and (2) adaptively managing their tree planting activities to change planting tactics and strategies to respond to observations of tree success (*e.g.,* making sure to plant trees so that the root flare is above ground after observing lower survival rates for trees planted too deeply and without a visible root flare; Mincey and Vogt 2014).

Can urban greening improve the capacity of individuals and communities to deal with the pressures of the Anthropocene?

While the social benefits of urban greening and connections to improved urban quality of life and human and community wellbeing are clear, research has not yet explicitly connected participation of individuals, organizations, or neighborhood/community groups in urban greening activities to their ability to respond to the challenges of the Anthropocene or the impacts of climate change.[4] The previous section described human capital in the form of satisfaction with personal yards as well as the neighborhood, ownership of the aesthetic appearance of these

[4] For instance, a recent special issue of *Landscape & Urban Planning* on green infrastructure and climate change (vol. 38, June 2015; editorial: Jim et al. 2015) included mostly articles about the ability of the urban forest to physically ameliorate the impacts of climate change, with just three pieces examining social aspects (concerning knowledge among residents of a Chinese city [Byrne et al. 2015]; an Indonesian city's residents' valuation of the benefits of green infrastructure in the context of climate change [Vollmer et al. 2015]; and, the barriers to widespread implementation of green infrastructure for climate adaptation [Matthews et al. 2015]), none of which explicitly examined tree planting or community capacity.

spaces, not to mention the individual experience and expertise accrued through participating (or even organizing) tree planting; and, social capital in the form of neighborhood ties and cohesion, neighborhood empowerment and capacity to self-organize, organizational partnerships, and adaptive capacity. These manifestations of human and social capital could be important to the ability of a neighborhood or community in responding to the various pressures of the Anthropocene.

Collective action, social capital, and the trust and reciprocity required therein are critical to a community's adaptive capacity (Adger 2003). *Adaptive capacity* is defined as the ability of a community to respond to and manage change or disturbances, both exogenous and endogenous, and is highly linked to trust and reciprocity, and the strength of relationships between individuals (*i.e.,* social capital; *ibid.*). Adger (2003) argues that adaptive capacity can make a community more capable of coping with the potential change and uncertainty posed by climate change as well as adapting to other adverse circumstances. A theoretical example of adaptive capacity could be neighbors organizing to build a small cooling shelter in a neighborhood park to cope with the increasing frequency and magnitude of extreme heat events as a result of climate change. Particularly in marginalized communities where the established social order results in inadequate provision of public goods and services, social capital can be crucial and can substitute where the government fails (*ibid.*). Tree planting, as a type of collective action, offers an opportunity for the strengthening of within-community social capital such as neighborhood ties and social cohesion as well as the creation of partnerships and networks with external entities, which could help a marginalized and underserved community build the capacity needed to improve the neighborhood through crime protection efforts or mitigate local urban heat island impacts and improve environmental quality through creation of pocket parks. Given that urban tree canopy cover is in some cities inequitably distributed, with less canopy cover in low-income neighborhoods (Heynen 2006; Heynen et al. 2006; Wilson and Lindsey 2009), tree-planting activities in marginalized areas therefore have the dual benefits of increasing canopy cover while potentially building social capital and adaptive capacity.

Distributional inequities of urban greening activities in the Anthropocene

It is important to note at this juncture that organizations that engage in urban greening activities may not systematically evaluate the distribution of those activities (and hence the

benefits therefrom) in neighborhoods across a city. For instance, collaborative nonprofit-neighborhood tree planting is at risk of resulting in uneven and inequitable distribution of trees and the ecosystem services they provide (Watkins et al. 2016). These organizations may rely on applications from neighborhoods or groups that self-identify as being interested in tree planting, or may require a certain level of investment (either monetary, or in the form of a certain number of volunteers, or a required level of post-planting follow-up tree care), and this might systematically bias against traditionally underserved neighborhoods that are low in resources (*ibid.*). Watkins et al. (2016) found that nonprofit street tree plantings across four U.S. cities were significantly less likely to occur in neighborhoods (U.S. Census block groups) with higher tree canopy cover, higher household income, or proportions of African American or Hispanic residents, and that when canopy cover or income was low, plantings were even less likely to occur in minority neighborhoods. Landry and Chakraborty (2009) observed similar disparities in tree cover in the public right-of-way (*i.e.,* canopy cover of street trees) in Tampa, Florida. However, inequities in tree planting or canopy cover is not universal across all cities: for instance, Berland et al. (2015) found no relationship between income, race, or ethnicity and canopy cover and that terrain alone explains distribution of trees in Cincinnati, Ohio. Thus, one of the challenge for urban forest practitioners for achieving a sustainable and inclusive Anthropocene is to make sure we consider which neighborhoods are served via tree planting and other urban greening activities, as well as the context in which greening activities occur.

Conclusions

Engagement of urban greening with the global dialogue about the future of cities

The years 2014-2016 have been big for sustainability internationally, and not only because each of the three years were consecutively declared the warmest years on record (NOAA 2016). In September 2015, the United Nation (UN) General Assembly adopted the Sustainable Development Goals (SDGs), 17 goals inclusive of 169 specific targets that set the global sustainability agenda for the 2015-2030 period (UN 2015). The SDGs set specific indicators that communities and nations should strive to meet, such as solving hunger and poverty, ensuring energy access, but also preserving ecosystem integrity (UN 2015). Goal 11 is specifically targeted towards cities ("Make cities and human settlements inclusive, safe, resilient and

sustainable"), and since over half of people live in them, cities will be key players in implementing all 17 goals (*ibid.*). In December 2015, the Paris Climate Agreement emerged from the 21st UN Conference of the Parties to the UN Framework Convention on Climate Change (COP21) meeting (UNFCCC 2016). This landmark agreement (ratified by 126 parties as of November 2016 when it entered into force) aims to ensure that the Earth maintains less than a 2° C (3.6° F) rise in global average temperature associated with climate change, and to do so will require significant reductions in greenhouse gases (*ibid.*). The Paris Agreement will require substantial action on the part of cities in meeting the reductions in greenhouse gas emissions committed to by the 197 countries that submitted 'intended nationally determined contributions' (INDCs; *ibid.*). Finally, in October 2016, the UN 'Habitat III' conference (full name: Conference on Housing and Sustainable Urban Development) provided guidance to cities in meeting the Paris Agreement as well as a post-2015 agenda for global sustainable development in cities (the adopted Habitat III policy document 'New Urban Agenda' is available on the conference website; UN Habitat III 2016).

There is significant opportunity for the urban forestry and urban greening community to contribute to these global efforts towards sustainability as follows:

1. Continue to engage in the types of transdisciplinary efforts that have recently come to characterize urban forestry research and practice (*e.g.,* Campbell et al. 2015; Vogt et al. *in review*) and are frequently called for as part of the urban sustainability science-policy-practice interface (McAllister and Taylor 2015; Simon and Schiemer 2015; McDonnell and MacGregor-Fors 2016; McPhearson et al. 2016);
2. Be sure that greening activities (including planting, stewardship, and monitoring of green infrastructure in cities) contribute to the implementation and monitoring of the Sustainable Development Goals, in particular Goal 11 which calls for "inclusive, safe, resilient and sustainable" cities (UN 2015);
3. Contribute data from urban forestry and urban greening activities (*e.g.,* tree planting locations, urban forest inventory data, data about the human investment and other costs collected during stewardship and maintenance of urban greenspaces) to understanding and monitoring progress towards sustainability in our cities; and,

4. Participate as often as possible and at all levels (neighborhoods, cities, states and communities) in the global dialogue about what our future on planet Earth should be (*a la* the SDGs, and the post-2015 New Urban Agenda from Habitat III, *etc.*).

A final thought experiment

In closing, I invite the reader to join me in a brief thought experiment. Recall that sustainability in the Anthropocene is about meeting the needs of human communities without compromising the ecological integrity of our planet by overusing natural resources and polluting our land, air, and water (Steffen et al. 2015b; Raworth 2012; Leach et al. 2013). If the main question lurking in this piece is, *How can we in the urban forestry and urban greening communities help our cities deal with the challenges of the Anthropocene and foster transitions to sustainability?*, then would not the best way to do this be to keep the needs of human communities and the ecological integrity of planet Earth constantly in our mind during our daily professional practice? Consider the following hypothetical questions (Figure 2):

Figure 2. An invitation for to urban forestry and urban greening to perpetuate dialogue and action towards sustainability in the Anthropocene. (Background photo: Lake Michigan over rooftops in the City of Chicago. *Photo credit: J. Vogt)*

- What if urban greening could contribute not just to lower energy costs, but to community conversations about going off grid or switching to alternative, zero-carbon-emissions energy sources?
- What urban greening could inspire neighborhoods to create a sharing economy, where neighbors who had engaged in tree planting together could share tools and instead of each household owning one of everything and needlessly consuming the Earth's material resources?
- What if urban greening could build citizen ability for political advocacy for sustainable energy technologies, or for inclusive politics and inclusive policies that help all members of human society meet their basic needs?
- What if urban greening could generate a truly local foods movement by creating networks of community gardens, food forests, and edible pocket parks all over the city?
- What if urban greening could build communities with greater capacity to respond to storm events, to check on one another during an electricity outage or power surge, to create networks and partnership that ensure swift disaster responses when required, to self-organize to clean up after storm damage, or to set up cooling shelters for extreme heat events?
- What if urban greening could empower households to reduce their automobile use, and instead walk or bike down aesthetically pleasing, shaded pathways?

What if all urban greening activities sought to help meet human needs while respecting Earth's ecological limits, and move our planet and human society towards true sustainability in the Anthropocene?

There are many out there already participating in dialogue and action. I invite you to join us.

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References

Adger WN (2003). Social capital, collective action, and adaptation to climate change. *Economic Geography*, 79:387–404.

Armson D, Stringer P, Ennos AR (2012). The effect of tree shade and grass on surface and globe temperatures in an urban area. *Urban Forestry & Urban Greening*, 11:245–255, doi:10.1016/j.ufug.2012.05.002.

Asara V, Otero I, Demaria F, Corbera E (2015). Socially sustainable degrowth as a social–ecological transformation: Repoliticizing sustainability. *Sustainability Science*, 10:375–384, doi:10.1007/s11625-015-0321-9.

Bell JF, Wilson JS, Liu GC (2008). Neighborhood greenness and 2-year changes in body mass index of children and youth. *American Journal of Preventive Medicine*, 35:547–53, doi:10.1016/j.amepre.2008.07.006.

Berland A, Schwarz K, Herrmann DL, Hopton ME (2015). How environmental justice patterns are shaped by place: Terrain and tree canopy in Cincinnati, Ohio, USA. *Cities and the Environment*, 8:1.

Brondizio ES, O'Brien K, Bai X, Biermann F, Steffen W, Berkhout F, Cudennec C, Lemos MC, Wolfe A, Palma-Oliveira J, et al. (2016). Re-conceptualizing the Anthropocene: A call for collaboration. *Global Environmental Change*, 39:318-327, doi:10.1016/j.gloenvcha.2016.02.006.

Byrne JA, Lo AY, Jianjun Y (2015). Residents' understanding of the role of green infrastructure for climate change adaptation in Hangzhou, China. *Landscape & Urban Planning*, 138:132–143, doi:10.1016/j.landurbplan.2015.02.013.

Coleman JS (1988). Social capital in the creation of human capital. *American Journal of Sociology*, 94:S95-S120, doi:10.1086/228943.

Collins CR, Neal JW, Neal ZP (2014). Transforming individual civic engagement into community collective efficacy: The role of bonding social capital. *American Journal of Community Psychology*, 54:328–336, doi:10.1007/s10464-014-9675-x.

Conway TM (2016). Tending their urban forest - resident motivations for tree planting and removal. *Urban Forestry & Urban Greening*, 17:23–32, doi:10.1016/j.ufug.2016.03.008.

Costanza R, D'Arge R, Groot R De, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill R V, Paruelo J, et al. (1997). The value of the world's ecosystem services and natural capital. *Nature*, 387:253–260.

Crowther TW, Glick HB, Covey KR, Bettigole C, Maynard DS, Thomas SM, Smith JR, Hintler G, Duguid MC, Amatulli G, et al. (2015). Mapping tree density at a global scale. *Nature*, 525:201–205, doi:10.1038/nature14967.

Crutzen PJ (2002). Geology of mankind. *Nature*, 415:23, doi:10.1038/415023a.

Donovan GH, Mills J (2014). Environmental Justice and Factors that Influence Participation in Tree Planting Programs in Portland, Oregon, U.S. *Arboriculture & Urban Forestry*, 40:70–77.

Donovan GH, Butry DT (2011). The effect of urban trees on the rental price of single-family homes in Portland, Oregon. *Urban Forestry & Urban Greening*, 10:163–168, doi:10.1016/j.amepre.2012.09.066.

Driscoll AN, Ries PD, Tilt JH, Ganio LM, (2015). Needs and barriers to expanding urban forestry programs: An assessment of community officials and program managers in the Portland – Vancouver metropolitan region. *Urban Forestry & Urban Greening*, 14:48–55, doi:10.1016/j.ufug.2014.11.004.

Gerhold HD (2007). Origins of urban forestry. In: "Urban and Community Forestry in the Northeast" (Kuser JE ed). Springer, New York, New York, USA, pp. 1-23.

Eisenman TS (2013). Frederick Law Olmsted, green infrastructure, and the evolving city. *Journal of Planning History*, 12:287–311, doi:10.1177/1538513212474227.

Faber-Taylor A, Kuo FE, Sullivan WC (2001). Coping with ADD: the surprising connection to green play settings. *Environment and Behavior*, 33:54–77, doi:10.1177/00139160121972864.

Fisher DR, Svendsen ES, Connolly JJ (2015). Urban environmental stewardship and civic engagement: How planting trees strengthens the roots of democracy. Routledge, New York, New York, USA, pp. 139.

Gowdy J, Krall L (2013). The ultrasocial origin of the Anthropocene. *Ecological Economics*, 95:137–147, doi:10.1016/j.ecolecon.2013.08.006.

Heynen N (2006). Green urban political ecologies: Toward a better understanding of inner-city environmental change. *Environment and Planning A*, 38:499–516, doi:10.1068/a37365.

Heynen N, Perkins HA, Roy P (2006). The political ecology of uneven urban green space. *Urban Affairs Review*, 42:3-25, doi:10.1177/1078087406290729.

Holtan MT, Dieterlen SL, Sullivan WC (2014). Social life under cover: Tree canopy and social capital in Baltimore, Maryland. *Environment and Behavior*, doi:10.1177/0013916513518064.

(IPCC) Intergovernmental Panel on Climate Change (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. [online June 19 2016] http://ar5-syr.ipcc.ch/ipcc/ipcc/resources/pdf/IPCC_SynthesisReport.pdf

Jim CY, Lo AY, Byrne JA (2015). Charting the green and climate-adaptive city. *Landscape & Urban Planning*, 138:51–53, doi:10.1016/j.landurbplan.2015.03.007.

Kallis G, Kerschner C, Martinez-Alier J (2012). The economics of degrowth. *Ecological Economics*, 84:172–180, doi:10.1016/j.ecolecon.2012.08.017.

Kallis G, Demaria F, D'Alisa G (2014). Introduction: Degrowth. In: "Degrowth: A vocabulary for a new era" (D'Alisa G, Demaria F, Kallis G eds). Routledge, London, p. 1–17.

Kardan O, Gozdyra P, Misic B, Moola F, Palmer LJ, Paus T, Berman MG (2015). Neighborhood greenspace and health in a large urban center. *Scientific Reports*, 5:11610, doi:10.1038/srep11610.

Konijnendijk CC, Ricard RM, Kenney A, Randrup TB (2006). Defining urban forestry – A comparative perspective of North America and Europe. *Urban Forestry & Urban Greening*, 4:93–103, doi:10.1016/j.ufug.2005.11.003.

Kuo FE, Sullivan WC, Coley RL, Brunson L (1998). Fertile ground for community: Inner-city neighborhood common spaces. *American Journal of Community Psychology*, 26:823–851.

Lachowycz K, Jones AP (2014). Does walking explain associations between access to greenspace and lower mortality? *Social Science and Medicine*, 107:9–17, doi:10.1016/j.socscimed.2014.02.023.

Landry SM, Chakraborty J (2009). Street trees and equity: evaluating the spatial distribution of an urban amenity. *Environment and Planning A*, 41:2651–2670, doi:10.1068/a41236.

Leach M, Raworth K, Rockström J (2013). Between social and planetary boundaries: navigating pathways in the safe and just space for humanity. In: "World Social Science Report 2013: Changing Global Environments" (International Social Science Council/UNESCO ed). OECD and Unesco, Paris, France, pp. 84-89. http://dx.doi.org/10.1787/9789264203419-10-en.

Lewicka M (2005). Ways to make people active: The role of place attachment, cultural capital, and neighborhood ties. *Journal of Environmental Psychology*, 25:381–395, doi:10.1016/j.jenvp.2005.10.004.

Livesley SJ, McPherson GM, Calfapietra C (2016). The Urban Forest and Ecosystem Services: Impacts on Urban Water, Heat, and Pollution Cycles at the Tree, Street, and City Scale. *Journal of Environment Quality*, 45:119–124, doi:10.2134/jeq2015.11.0567.

Lochner K, Kawachi I, Kennedy BP (1999). Social capital: A guide to its measurement. *Health & Place*, 5:259–70.

Lu JWT, Svendsen ES, Campbell LK, Greenfeld J, Braden J, King KL, Falxa-Raymond N (2010). Biological, social, and urban design factors affecting young street tree mortality in New York City. *Cities and the Environment*, 3:1–15.

Matthews T, Lo AY, Byrne JA (2015). Reconceptualizing green infrastructure for climate change adaptation: Barriers to adoption and drivers for uptake by spatial planners. *Landscape & Urban Planning*, 138:155–163, doi:10.1016/j.landurbplan.2015.02.010.

McAllister RR, Taylor BM (2015). Partnerships for sustainability governance: A synthesis of key themes. *Current Opinion in Environmental Sustainability*, 12:86–90, doi:10.1016/j.cosust.2015.01.001.

McDonnell MJ, MacGregor-Fors I (2016). The ecological future of cities. *Science*, 352:936–8, doi:10.1126/science.aaf3630.

McPhearson T, Pickett STA, Grimm NB, Niemela J, Alberti M, Elmqvist T, Weber C, Haase D, Breuste J, Qureshi S (2016). Advancing urban ecology toward a science of cities. *Bioscience*, 66:198–212, doi:10.1093/biosci/biw002.

McPherson EG, Kendall A (2014). A life cycle carbon dioxide inventory of the Million Trees Los Angeles program. *International Journal of Life Cycle Assessment*, 19:1653–1665, doi:10.1007/s11367-014-0772-8.

McPherson EG, van Doorn N, de Goede J (2016). Structure, function and value of street trees in California, USA. *Urban Forestry & Urban Greening*, 17:104–115, doi:10.1016/j.ufug.2016.03.013.

Mincey SK, Vogt JM (2014). Watering strategy, collective action, and neighborhood-planted trees: A case study of Indianapolis, Indiana, U.S. *Arboriculture & Urban Forestry*, 40:84–95.

Morani A, Nowak DJ, Hirabayashi S, Calfapietra C (2011). How to select the best tree planting locations to enhance air pollution removal in the MillionTreesNYC initiative. *Environmental Pollution*, 159:1040–1047, doi:10.1016/j.envpol.2010.11.022.

Moskell C, Allred SB (2013). Residents' beliefs about responsibility for the stewardship of park trees and street trees in New York City. *Landscape & Urban Planning*, 120:85–95, doi:10.1016/j.landurbplan.2013.08.002.

(NOAA) National Oceanographic and Atmospheric Administration Earth System Research Laboratory Global Monitoring Division (2015). Trends in Atmospheric Carbon Dioxide. Web site. [online January 24 2017] http://www.esrl.noaa.gov/gmd/ccgg/trends/.

(NOAA) National Oceanographic and Atmospheric Administration National Centers for Environmental Information (2016). State of the Climate. Web site. [online June 19 2016] https://www.ncdc.noaa.gov/sotc/.

Nowak DJ, Hirabayashi S, Bodine A, Hoehn R (2013). Modeled PM2.5 removal by trees in ten U.S. cities and associated health effects. *Environmental Pollution*, 178:395–402, doi:10.1016/j.envpol.2013.03.050.

Nowak DJ, Hirabayashi S, Bodine A, Greenfield E (2014). Tree and forest effects on air quality and human health in the United States. *Environmental Pollution*, 193:119–129, doi:10.1016/j.envpol.2014.05.028.

O'Neill DW (2012). Measuring progress in the degrowth transition to a steady state economy. *Ecological Economics*, 84:221–231, doi:10.1016/j.ecolecon.2011.05.020.

Pataki DE, Alberti M, Cadenasso ML, Felson AJ, McDonnell MJ, Pincetl S, Pouyat R, Setälä H, Whitlow TH (2013). Urban greening needs better data. Correspondence. *Nature*, 502:624, doi:10.1038/502624a.

Pataki DE, Alig RJ, Fung AS, Golubiewski NE, Kennedy C a., Mcpherson EG, Nowak DJ, Pouyat R V., Romero Lankao P (2006). Urban ecosystems and the North American carbon cycle. *Global Change Biology*, 12:2092–2102, doi:10.1111/j.1365-2486.2006.01242.x.

Pataki DE, Carreiro MM, Cherrier J, Grulke NE, Jennings V, Pincetl S, Pouyat R V., Whitlow TH, Zipperer WC (2011). Coupling biogeochemical cycles in urban environments: Ecosystem services, green solutions, and misconceptions. *Frontiers in Ecology and the Environment*, 9:27–36, doi:10.1890/090220.

Pincetl S, Gillespie T, Pataki DE, Saatchi S, Saphores J-D (2013). Urban tree planting programs, function or fashion? Los Angeles and urban tree planting campaigns. *GeoJournal*, 78:475–493, doi:10.1007/s10708-012-9446-x.

Ricard R (2005). Shade trees and tree wardens: revising the history of urban forestry. *Journal of Forestry*, 103:230–233.

Roman LA, Walker LA, Martineau CM, Muffly DJ, MacQueen SA, Harris W (2015). Stewardship matters: Case studies in establishment success of urban trees. *Urban Forestry & Urban Greening*, 14:1174–1182, doi:10.1016/j.ufug.2015.11.001.

Sampson RJ, Graif C (2009). Neighborhood social capital as differential social organization: Resident and leadership dimensions. *American Behavioral Scientist*, 52:1579–1605, doi:10.1177/0002764209331527.

Sampson RJ, Morenoff JD, Earls F (1999). Beyond social capital: Spatial dynamics of collective efficacy for children. *American Sociological Review*, 64:633–660.

Setälä H, Viippola V, Rantalainen AL, Pennanen A, Yli-Pelkonen V (2013). Does urban vegetation mitigate air pollution in northern conditions? *Environmental Pollution*, 183:104–112, doi: 10.1016/j.envpol.2012.11.010.

Shandas V (2015). Neighborhood change and the role of environmental stewardship: A case study of green infrastructure for stormwater in the city of Portland, Oregon, USA. *Ecology & Society*, 20:art. 16, pp. 17, doi:10.5751/ES-07736-200316.

Silvera Seamans G (2013). Mainstreaming the environmental benefits of street trees. *Urban Forestry & Urban Greening*, 12:2–11, doi:10.1016/j.ufug.2012.08.004.

Simon D, Schiemer F (2015). Crossing boundaries: complex systems, transdisciplinarity and applied impact agendas. *Current Opinion in Environmental Sustainability*, 12:6–11, doi:10.1016/j.cosust.2014.08.007.

Sommer R, Learey F, Summit J, Tirrell M (1994a). The social benefits of resident involvement in tree planting. *Journal of Arboriculture*, 20:170–175.

Sommer R, Learey F, Summit J, Tirrell M (1994b). Social benefits of resident involvement in tree planting: Comparison with developer-planted trees. *Journal of Arboriculture*, 20:323–328.

Steffen W, Broadgate W, Deutsch L, Gaffney O, Ludwig C (2015a). The trajectory of the Anthropocene: The Great Acceleration. *The Anthropocene Review*, 2:81–98, doi:10.1177/2053019614564785.

Steffen W, Richardson K, Rockström J, Cornell S, Fetzer I, Bennett E, Biggs R, Carpenter SR, de Wit CA, Folke C, et al. (2015). Planetary Boundaries: Guiding human development on a changing planet. *Science*, 347:1259855, doi:10.1126/science.1259855.

Stone B, Vargo J, Habeeb D (2012) Managing climate change in cities: Will climate action plans work? *Landscape & Urban Planning*, 107:263–271, doi:10.1016/j.landurbplan.2012.05.014.

Summit J, McPherson EG (1998). Residential tree planting and care: A study of attitudes and behavior in Sacramento, CA. *Journal of Arboriculture*, 24:89–97.

Summit J, Sommer R (1998). Urban tree-planting programs – A model for encouraging environmentally protective behavior. *Atmospheric Environment*, 32:1–5.

Ulrich RS (1984). View through a window may influence recovery from surgery. *Science*, 224:42-421.

Ulrich RS, Simons RF, Losito BD, Fiorito E, Miles MA, Zelson M (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology* 11:201–230.

United Nations (UN) Conference on Housing and Sustainable Urban Development ('Habitat III') (2016). Habitat III. Web site. [online June 19 2015] https://www.habitat3.org.

United Nations (UN) Department of Economic and Social Affairs Population Division (2014). *World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352)*. Web site. [online June 19 2016] http://esa.un.org/unpd/wup/highlights/wup2014-highlights.pdf.

United Nations (UN) (2015). Transforming our World: The 2030 Agenda for Sustainable Development, A/RES/70/1. United Nations, New York, New York, USA, pp. 41. [online June 19 2016] https://sustainabledevelopment.un.org/post2015/transformingourworld/publication.

United Nations (UN) Development Programme (2015). Sustainable Development Goals Overview. Web site. [online June 19 2016] http://www.undp.org/content/undp/en/home/sdgoverview/post-2015-development-agenda.html.

United Nations Framework Convention on Climate Change (UNFCC) (2017). The Paris Agreement. Web site. [online January 24 2017] http://unfccc.int/paris_agreement/items/9485.php.

Vogt JM, Fischer BC (2014). A protocol for citizen science monitoring of recently-planted urban trees. *Cities and the Environment*, 7:4.
Vogt J, Roman LA, Brandt L, Ries P (In review). Urban forestry for the Anthropocene: Transdisciplinary efforts for meeting new challenges.

Vogt JM, Watkins SL, Mincey SK, Patterson MS, Fischer BC (2015). Explaining planted-tree survival and growth in urban neighborhoods: A social–ecological approach to studying recently-planted trees in Indianapolis. *Landscape & Urban Planning*, 136:130–143, doi:10.1016/j.landurbplan.2014.11.021.

Vollmer D, Prescott MF, Padawangi R, Girot C, Grêt-Regamey A (2015). Understanding the value of urban riparian corridors: Considerations in planning for cultural services along an Indonesian river. *Landscape & Urban Planning*, 138:144–154, doi:10.1016/j.landurbplan.2015.02.011.

Watkins SL, Mincey SK, Vogt J, Sweeney SP (2016). Is planting equitable? An examination of the spatial distribution of nonprofit urban tree-planting programs by canopy cover, income, race, and ethnicity. *Environment and Behavior*, doi:10.1177/0013916516636423.

Waters CN, Zalasiewicz J, Summerhayes C, Barnosky AD, Poirier C, Galuszka A, Cearreta A, Edgeworth M, Ellis EC, Ellis M, et al. (2016). The Anthropocene is functionally and stratigraphically distinct from the Holocene. *Science*, 351:aad2622–aad2622, doi:10.1126/science.aad2622.

Westphal LM (2003). Social aspects of urban forestry: Urban greening and social benefits: a study of empowerment outcomes. *Journal of Arboriculture*, 29:137–147.

Widney S, Fischer BC, Vogt J (2016). Tree mortality undercuts ability of tree-planting programs to provide benefits: results of a three-city study. *Forests*, 7:65, doi:10.3390/f7030065.

Wilson JS, Lindsey GH (2009). Identifying urban neighborhoods for tree canopy restoration through community participation. In: "Planning and Socioeconomic Applications: Geotechnologies and the Environment, Vol. 1" (Gatrell JD, Jensen RR eds). Springer, Berlin, Germany, pp. 29-42.

Wolf KL (2005a). Trees in the small city retail business district: Comparing resident and visitor perceptions. *Journal of Forestry*, 103:390–395.

Wolf KL (2005b). Business district streetscapes, trees, and consumer response. *Journal of Forestry*, 103:396–400.

Wolf KL, Measells MK, Grado SC, Robbins AST (2015). Economic values of metro nature health benefits: A life course approach. *Urban Forestry & Urban Greening*, 14:694–701, doi:10.1016/j.ufug.2015.06.009.

Wolfe MK, Mennis J (2012). Does vegetation encourage or suppress urban crime? Evidence from Philadelphia, PA. *Landscape & Urban Planning*, 108:112–122, doi:10.1016/j.landurbplan.2012.08.006.

Yang T-C, Matthews SA (2010). The role of social and built environments in predicting self-rated stress: A multilevel analysis in Philadelphia. *Health & Place*, 16:803–10, doi:10.1016/j.healthplace.2010.04.005.

Young RF (2013). Mainstreaming urban ecosystem services: A national survey of municipal foresters. *Urban Ecosystems*, 16:703–722, doi:10.1007/s11252-013-0287-2.

Zalasiewicz J, Waters CN, Williams M, Barnosky AD, Cearreta A, Crutzen P, Ellis E, Ellis MA, Fairchild IJ, Grinevald J, et al. (2015). When did the Anthropocene begin? A mid-twentieth century boundary level is stratigraphically optimal. *Quaternary International*, 383:196–203, doi:10.1016/j.quaint.2014.11.045.

Zhang B, Xie G di, Gao J xi, Yang Y (2014). The cooling effect of urban green spaces as a contribution to energy-saving and emission-reduction: A case study in Beijing, China. *Building and Environment*, 76:37–43, doi:10.1016/j.buildenv.2014.03.003.

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Zhu Hua Ning
David J. Nowak
Gary Watson

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