Sustainability Science for Urban Foresters and Arborists

By Jess Vogt and Rich Hauer

Sustainability science is the field of research, practice, and policy that seeks to find and implement solutions for an ecologically beneficial, socially inclusive, economically just, and authentically happy future, where all life can thrive and flourish on planet Earth. In this article, we explore key concepts from sustainability science, and we discuss examples relevant to arboriculture and urban forestry practice.

The Anthropocene: Surpassing the Earth's Planetary Boundaries

Earth has entered the Anthropocene—a new geologic epoch in which humans are the drivers of rapidly changing global and local environmental conditions (Steffen et al. 2015a). The pressures of the Anthropocene threaten the future of humanity: limited natural resources, pollution of air and water, and the degradation of ecosystem services (Steffen et al. 2015a). Climate change compounds all of these pressures (IPCC 2015). The majority of these impacts will be felt by urban areas; over 50 percent of people already live in cities, and by 2050, this will be 66 percent (United Nations 2014).

In order to live sustainably in the Anthropocene, sustainability scientists have identified nine key life-support systems that ensure life on Earth will persist (Figure 1; Rockström et al. 2009a; Rockström et al. 2009b; Steffen et al. 2015b). These planetary boundaries are the environmental, biological, and physical limits that we should not surpass if we desire to maintain the livability of the planet for people. These boundaries are analogous to walking near a cliff: human actions indicate we are collectively stepping closer and closer to the edge of the cliff. The boundaries, then, act as a guardrail, constructed several feet back from the edge. If we surpass a given boundary, we have not necessarily stepped off the cliff, but we are much, much closer to the edge and might fall off at any moment.

The breadth of human economic and development activity means we are stepping over the guardrail and closer to the edges of these cliffs (see *Examples of Human Activity*). Humanity has already exceeded the planetary boundaries for climate change, biosphere integrity, land system change, and biogeochemical flows (Steffen et al. 2015b). And for biosphere integrity and biogeochemical flows, scientists have evidence indicating we have already stepped off the cliff, meaning it will be extremely difficult if not impossible to reverse the damage done to our planet (Steffen et al. 2015b). This surpassing of planetary boundaries is why scientists argue the Earth has entered the Anthropocene (Steffen et al. 2015a; Steffen et al. 2015b).

Social Foundations: Creating a Safe and Just Operating Space for Humanity

And yet, a certain amount of human impact on the planet is necessary for sustenance of human life. Human societies rely on the Earth and its ecosystems for basic necessities, such as food, water, and energy. Furthermore,

Examples of Human Activity

Noted here are a few examples of human activity contributing to the surpassing of the planetary boundaries. (Planetary boundaries noted in bold text.)

Burning fossil fuels to produce electricity and transportation causes the emission of greenhouse gases, like carbon dioxide, which contribute to anthropogenic **climate change** and thereby threaten ecosystem functions and human livelihood.

Extraction of minerals and other raw materials used in consumer goods contributes to extensive degradation of Earth's ecosystems, causing species extinctions and compromising the **integrity of the biosphere**.

Industrial agriculture, to produce food and fiber for human consumption, has resulted in the **clearing of forests** and natural ecosystems. Agriculture requires significant amounts of **freshwater**, and often results in overuse of **nitrogen** and **phosphorous** fertilizers that cause algae blooms and furthers the loss of aquatic biodiversity.

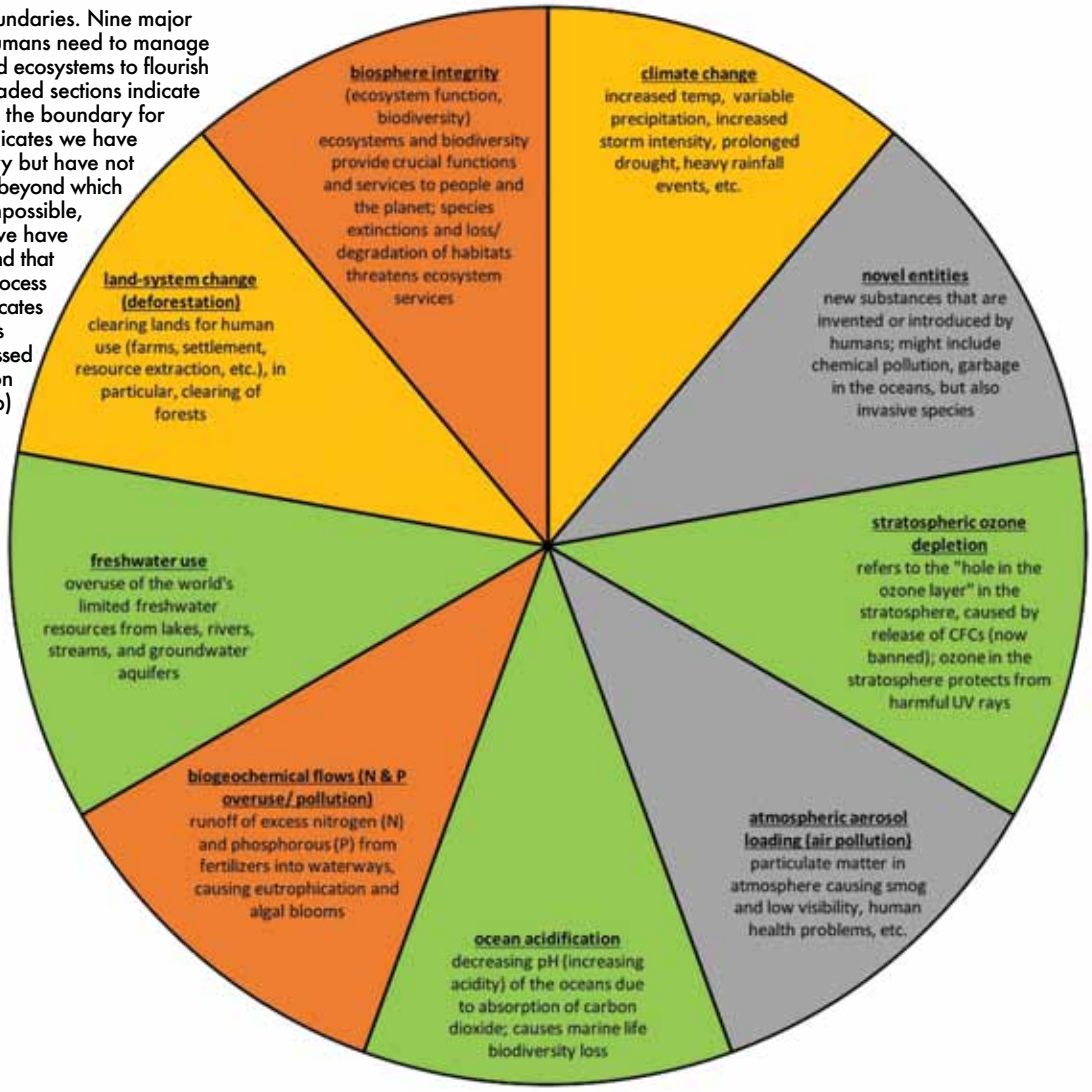

Figure 1. Planetary Boundaries. Nine major Earth processes that humans need to manage in order for humans and ecosystems to flourish on Earth. The green-shaded sections indicate we have not surpassed the boundary for this process, yellow indicates we have surpassed the boundary but have not yet crossed a threshold beyond which reversing damage is impossible, and orange indicates we have crossed the threshold and that the functioning of this process is threatened. Gray indicates a lack of data to assess whether we have surpassed this boundary. Based on Rockström et al. (2009b) and Steffen et al. (2015b).

it is also important that human societies ensure basic human rights, such as social equity, gender equality, meaningful work, and voice in decision-making. As such, eleven social foundations (Figure 2), or key human needs that must be met if humanity is to become truly sustainable, have been added to the planetary boundaries (Raworth 2012).

The place where human needs are met, and the Earth's environmental limits are not exceeded, is called "the safe and just space for humanity" (Figure 3; Raworth 2012). Our challenge in the Anthropocene is to strive to meet the desired social foundations, while not exceeding the planetary boundaries and thus causing irrevocable damage to Earth's life-support systems.

What Does That Mean for Urban Foresters and Arborists?

As urban foresters and arborists, much of our work already contributes to generating more ecologically sustainable cities in which people can enjoy a high quality of life. Trees provide benefits that improve urban environmental quality and human quality of life—carbon sequestration (e.g., Kovacs et al. 2013), stormwater management (e.g., Bartens et al. 2008), reduction of air pollution (e.g., Nowak et al. 2013a), improved human health (e.g., Nilsson et al. 2011), and social cohesion (e.g., Weinstein et al. 2015). What follows are two specific examples of urban forestry and arboricultural activities contributing to meeting the social foundations, while staying within the planetary boundaries.

Example #1: Urban forests, energy use, and climate change

Those in our field are well attuned to the shade and energy savings benefits that trees provide. For instance, the most recent urban forest ecosystem services analysis of trees in the Chicago, Illinois, U.S., region estimated that trees near residential buildings reduce energy costs by approximately USD $44 million per year (Nowak et al. 2013b). In this

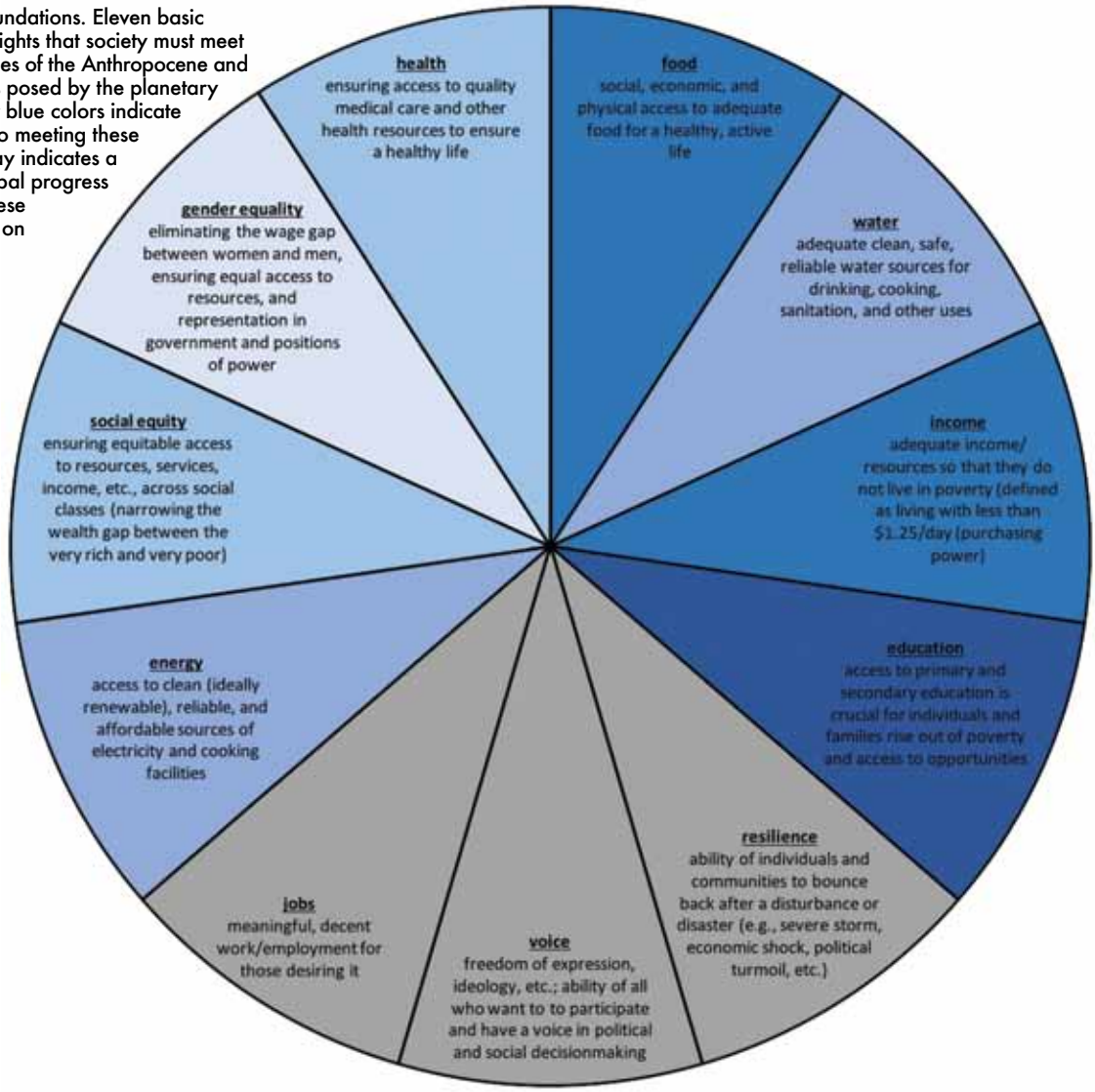

Figure 2. Social Foundations. Eleven basic needs and human rights that society must meet despite the challenges of the Anthropocene and environmental limits posed by the planetary boundaries. Darker blue colors indicate that we are closer to meeting these needs globally. Gray indicates a lack of data on global progress towards meeting these foundations. Based on Raworth (2012).

way, trees make electricity and gas bills more affordable for renters and homeowners living in these areas.

On a citywide scale, climate models suggest that tree canopy can have a substantial overall impact on urban temperatures (Solecki et al. 2005). The cooling properties of urban trees might be particularly important as our cities' summer temperatures warm with climate change. Extreme heat events and heat waves will become more frequent under the effects of climate change, and can cause significant human casualties. For instance, the Cook County medical examiner's office estimated that 739 individuals died due to heat-related causes in a seven-day heatwave in July of 1995 in Chicago (Thomas 2015). This number is comparable to the annual number of homicide deaths in Chicago (Willis and Hernandez 2016). Trees and vegetation simultaneously reduce urban temperatures, lower energy demand, and even decrease the risk of rolling electricity blackouts, thereby lessening human vulnerability to one aspect of climate change.

In the language of the planetary boundaries and social foundations, trees in cities can help communities cope with climate change, while helping meet the basic needs of energy and human health. Incidentally, treed landscapes also are correlated with lower crime rates (Weinstein et al. 2015).

Example #2: Invasive forest pests and diseases as a novel entity

Emerald ash borer (EAB) and Dutch elm disease (DED) are examples of invasive pests of urban forests that in the lingo of planetary boundaries would be called "novel entities."

Novel entities are new substances invented or introduced by humans that pollute our ecosystems. Invasive

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species; trash that gathers in parks, boulevards, and vacant lots; and chemicals from exhaust running off the surface of streets and into our waterways—are all examples of novel entities that impact our urban forests.

If managed poorly, EAB and DED may kill large percentages of trees in the impacted genera each year (Vannatta et al. 2012). Human health can be impacted by these pest infestations as well. Donovan and colleagues (2013) observed higher rates of mortality due to respiratory-tract or cardiovascular disease in communities with longer-running infestations of EAB (and presumably higher tree mortality and lower tree cover). Thus, managing EAB populations using insecticide treatments can not only control spread of the pest but also preserve the human health and other benefits of the urban forest (Vannatta et al. 2012).

Unavoidable Environmental Constraints and Essential Human Needs

The ideas of the Anthropocene, planetary boundaries, and social foundations have two main utilities for arborists and urban foresters.

First, the concept of unavoidable constraints in the context of essential needs (Figure 3) is a useful heuristic for thinking about how systems function.

Whether we're managing all of the trees on a college campus, maintaining the street trees for a municipality, planning the forestry agenda for an entire region, or even running a nursery—in any system that we work in, our actions are often constrained by the environmental or physical limitations of the system. We might be working in a water-limited area, plagued by drought. We might be planting trees in particularly degraded or low-quality

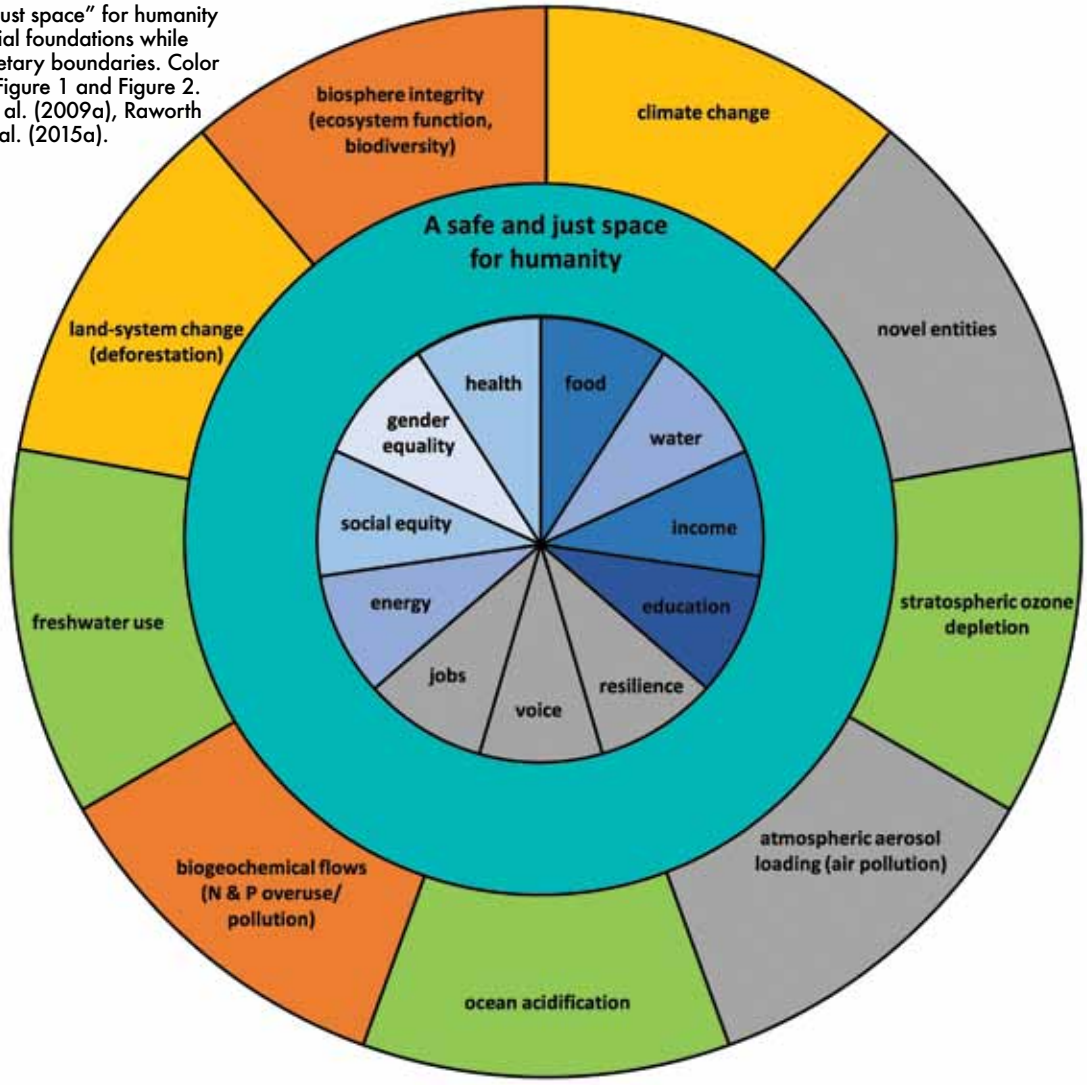

Figure 3. A "safe and just space" for humanity means meeting the social foundations while staying within the planetary boundaries. Color key is the same as for Figure 1 and Figure 2. Based on Rockström et al. (2009a), Raworth (2012), and Steffen et al. (2015a).

soils. The species pallet available to us is likely limited by the climate of the region. A California live oak (*Quercus agrifolia*), for example, native to the Los Angeles, California, area, is not an appropriate tree for Chicago, Illinois. We are further limited in our planting spaces by competition for space with other forms of urban infrastructure, like roads, sewers, buildings, and power lines.

However, regardless of the constraints, there is usually a basic set of socially constructed criteria or human needs that we must meet. For instance, we must meet a need for human safety by making sure that there are no high-risk trees in our urban forest, especially in areas where the consequence of tree failure exceeds our willingness to accept the risk. Removing a tree before it fails and determining at what point to remove (or preserve) it can be challenging, especially when historic significance comes into play. The Pioneer Cabin Tree and Wye Oak in North America, and the Anne Frank tree in Europe, are examples of trees that failed after storms due to decay even after attempts to preserve these historically significant specimens.

Additional constraints might include a need for shade and a comfortable outdoor temperature along a major walking path within a city. We also desire to maintain a clean source of drinking water by using trees to filter stormwater runoff of pollutants, and promote groundwater infiltration.

Providing safe, meaningful, and well-compensated work to our employees is yet another a social need. As an appendix to this article, readers may request a worksheet to think through what specific environmental or physical constraints and basic social needs are in effect for your urban forest.

Second, by thinking more explicitly about what "safe and just" and sustainable cities means to us as urban forestry and arboriculture professionals, we will enable our profession to build a vocabulary through which we can communicate with a broader and more global sustainability community. This mindset can help us create connections with others both inside and outside of our communities. (The worksheet appendix to this article contains a guide for brainstorming how each planetary boundary and social foundation relates to the urban forest in your community.)

As cities begin to reinvent themselves in the face of climate change and the other challenges of the Anthropocene, we should position our profession, through the trees and greenspaces we manage, at the forefront of this new sustainability agenda. There is tremendous opportunity for urban forestry and urban greening activities to align with city sustainability initiatives. Indeed, many urban foresters are already deeply involved in contributing to municipal climate change mitigation and adaptation initiatives, building partnerships across regions and sectors, and working to plan the next phase of sustainable development in cities. So our task—as professionals, but also as residents of cities and towns of all sizes—is to ask ourselves the question: How can we create a "safe and just" space for people and urban forests in our cities?

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Graphs courtesy of the authors.

To obtain the appendix to this article, please contact the editor (editor@isa-arbor.com).